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HENRY B. KÜMMEL, State Geologist

Iron Mines and Mining in New Jersey

BY

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State Geologist,

HENRY B. KÜMMEL.

* Died May 5, 1910.

LETTER OF TRANSMITTAL.

To His Excellency, J. Franklin Fort, Governor of the State of New Jersey and President of the State Printing Board:

SIR—I have the honor to submit through you to the State Printing Board a Report upon the Iron Mines and Mining in New Jersey, and to request that it be published as Volume VII of the Final Report Series of the State Geologist.

This report covers the entire history of the iron-mining industry in this State and presents in one place all the available data regarding the many iron mines and prospects which have been worked during the past century.

Yours respectfully,

HENRY B. KÜMMEL,

April 19th, 1910. *State Geologist.*

PREFACE.

The accompanying report was undertaken at the request of the State Geologist of New Jersey, with the aim of presenting in a single publication the major facts known concerning the distribution and manner of occurrence of iron ores of the State. Many items of interest with reference to the iron mines have been published in the various reports of the New Jersey Geological Survey, and much information relating to the history of the different mines has been given in them. This material, however, is scattered through about forty volumes of the Annual Reports of the Survey, and, since many of these are out of print, is inaccessible to those to whom it might be of service. Moreover, many of the mines that were formerly worked have been lost sight of, and others have changed names. It is, therefore, a difficult matter to follow the descriptions written at different times unless the successive reports are carefully compared for the express purpose of identifying the mines discussed. It is, nevertheless, very important to know their early history, if any correct idea of the permanency of the ore bodies is to be obtained. For these reasons it has seemed desirable that the information contained in the older reports be examined and its essential features be correlated with the results of later investigations. As the old reports are comparatively rare, it is thought probable that a re-statement of the many facts contained in them might be of value.

In the following pages everything of importance that has been published relating in any way to the iron-mining industry of the State has been collected, condensed and presented in such a manner as will prove convenient for reference to those who are interested in the subject. The literature has been scanned for items relating to the mines and for discussions of views on the

origin of the ore bodies. Practically every mine hole has been visited and every mine dump carefully examined, in the hope that it might throw light on the manner of formation of the ore. In connection with the areal mapping of the Highland region that was undertaken under the auspices of the United States Geological Survey, the geology of the northern portion of the State has been studied in detail by the geologists of the National and State surveys. The results of these various lines of investigation are indicated in a preliminary chapter. Preceding this is a brief history of iron-ore mining in the State. The different classes of ores are then discussed and the mines producing them are described.

The greatest stress is laid on the magnetite ores, because these are by far the most important, constituting as they do practically the whole of the State's present resources in iron ores. A summary of the views that have been held by various writers on the origin of these ores is given, and incidentally a summary of the opinions held as to the nature of the gneisses associated with them. The history of every mine that has ever produced ore, so far as is known, is briefly touched upon, and many explorations that never became producing mines are described. With this information at hand it ought to be possible to get some idea of the value of the various deposits and of the conditions under which they might be worked profitably.

In connection with the description of the ores, all of the available commercial analyses have been tabulated, and a number of the more complete ones have been collected. It was realized, however, that many of these analyses are faulty, consequently a new set of accurate analyses was made, which are published here for the first time. Since they are limited to the ore of mines that are active at the present day, they furnish little evidence as to the value of the ore in the many abandoned mines. Nevertheless, they give a better idea than has heretofore been obtainable of the general character of the ores as a whole.

It is fully recognized by the writer that the report contains little matter that is new—that it is mainly a compilation. It is hoped, however, that it will prove of value to those who desire to obtain in a single volume all the more important information

that has been published on the State's iron-ore resources. If it satisfies this demand, its existence is justified.

In the course of preparation of the report the author has been favored with the help of the mining men of the State, who, without exception, have done all in their power to contribute to its completeness. To all of these the author desires to express his thanks for the many courtesies extended him. Among those whose aid has been most valuable may be mentioned Mr. Edward Kelly, General Manager of the Wharton Steel Company; Mr. A. Munson, Superintendent of the Hibernia Mines; Mr. James Arthur, Superintendent of the Richard Mine; Mr. Duke Peckitt, Superintendent of the Mt. Hope Mines; Mr. Charles E. Hewitt, Secretary of the Ringwood Company; Mr. J. M. Clark, Secretary of the Hudson Iron Company, and Mr. B. F. Fackenthal, President of the Thomas Iron Company. Mr. Frederick A. Canfield has kindly read certain portions of the manuscript, and has added to it matter of considerable value.

To Mr. Thomas A. Edison special thanks are due. Mr. Edison not only placed at the disposal of the writer all the material collected by him during the course of his investigations of the iron ore resources of the Highlands, but also granted permission to use this material in any way that seemed desirable.

CHAPTER I.

INTRODUCTION.

CONTENTS.

BRIEF HISTORY OF IRON-ORE MINING IN NEW JERSEY.

The mining of iron ore in New Jersey began in the early years of the State's history, almost as soon as English settlers entered its borders. It is on record that Robert Morris owned iron works at Tinton Falls, Monmouth County, in 1685. Twenty-five years later (in 1710) the Dickerson mine at Succasunna was bought. Forges were in operation in 1716 at Whippany, in Morris County, and at Upper Freehold, in Monmouth County. These forges evidently obtained their ore locally, though we cannot be certain from what mines it came. Probably most of it was limonite, but some was surely magnetite. In 1742 the old charcoal furnace at Oxford, in Warren County, was built, and the magnetite mines in its vicinity were operated. The forges and furnaces at High Bridge, Hunterdon County, were built in 1754; the furnace at Ringwood, Passaic County, in 1762, and those at Charlottesburg and Long Pond (Greenwood Lake), in the same county, were constructed in 1763.

Many forges were in operation during the early years of the Revolution. According to a census in 1784, the State then had eight blast furnaces and 79 forges. Gordon, in his statistical table, published in 1834, has listed 12 blast furnaces and 108 forge fires. There were 14 forges in South Jersey at that time.

With the introduction of anthracite for smelting, the number of charcoal furnaces rapidly decreased, and the many forges were abandoned. In 1856 the number of active charcoal fur-

naces was only two, while the number of those using anthracite as a fuel was five, of which three were at Phillipsburg, one was at Boonton and one at Franklin, the latter having been built for the reduction of franklinite. A few of the forges continued to work intermittently to satisfy local demands, but finally all disappeared, until even their sites are now difficult to recognize. Among the last to cease operations were the forge at Dover, that in Ocean County, which was at work in 1866-7, and the following in the northern part of the State: Shippenport, Russia, Stockholm, Ryerson's at Bloomingdale, Powerville, Splitrock and Middle Forge. These were operated for short periods, at intervals, until 1879, but since that time have fallen into ruins.

Table I.—List of Forges Formerly Operated in New Jersey.[1]

Name.	*Location.*	*Remarks.*
	ATLANTIC COUNTY.	
	Monroe, Weymouth Township.	
	BERGEN COUNTY.	
	Schraalenberg.	According to Gordon's map.
	BURLINGTON COUNTY.	
	Hampton, Shamong Township.	
	CUMBERLAND COUNTY.	
	Manumuskin.	
	HUNTERDON COUNTY.	
Solitude,	Near High Bridge.	
	MIDDLESEX COUNTY.	
	Spottswood.	
	MONMOUTH COUNTY.	
	Imlaystown, Upper Freehold.	Built in 1716.
Jackson's,	Near Squankum.	
	MORRIS COUNTY.	
	Russia, Jefferson Township.	1775.
	Weldon, Jefferson Township.	
	Hurdtown, Jefferson Township.	

[1] This list and that of the charcoal furnaces is taken bodily from the Annual Report of the State Geologist for 1879, pp. 164–167.

Name.	*Location.*	*Remarks.*
Swedeland,	Milton, Jefferson Township.	1801.
	Petersburg, Jefferson Township.	Two forges, according to Gordon's map, at Petersburg.
	Woodstock, Jefferson Township.	1790.
	Upper Longwood, Jefferson Township.	
	Lower Longwood, Jefferson Township.	There have been 2 forges at Lower Longwood and in the Berkshire and Longwood Valleys. The map of Gordon has 6 in all.
	Berkshire Valley, Jefferson Township.	
Valley,	Near Baker's Mills, Roxbury Township.	1780.
Washington,	On Rockaway River, Rockaway Township.	1850.
Mount Pleasant,	Mount Pleasant, Rockaway Township.	In ruins.
Ætna,	Near Middle Forge, Rockaway Township.	Built about Revolution.
Middle,	Middle Forge, Rockaway Township.	1810.
Denmark,	Denmark, Rockaway Township. ship.	1800.
Timber Brook,	Southwest of Charlottesburg. Rockaway Township.	
Durham,	Southwest of Charlottesburg. Rockaway Township.	1811–1856.
Earle's,	Stony Brook, Pequannock Township.	1822–1856.
Decker's,	Rockaway Valley, Rockaway Township.	1846.
Dixon's,	Rockaway Valley, Rockaway Township.	1827.
Splitrock,	Splitrock, Rockaway Township.	About 1837.
Stickel's,	Meriden, Rockaway Township.	1790.
Righter's,	Meriden, Rockaway Township.	1820.
Beach Glen,	Beach Glen, Rockaway Township.	Built in 1760.
Hibernia,	Hibernia, Rockaway Township.	Gordon's map has two forges here.

Name.	*Location.*	*Remarks.*
Muir's, ...	On White Meadow Brook, Rockaway Township.	
	Rockaway, Rockaway Township.	There were 2 forges here, 1790–1805; and Gordon's map has 2 additional on Horse Pond Branch.
	Powerville, Boonton Township.	Built 1853.
	Boonton.	Gordon's map has 2 forges here.
Righter's, ...	Old Boonton, Hanover Township.	Built 1853.
Troy, ...	Troy, Hanover Township.	1745–1859.
Whippany, ...	Whippany, Hanover Township.	Built in 1710.
	Speedwell, Morris Township.	Gordon's map has 2 forges, W. & N. W. of Speedwell works.
	Morristown, Morris Township.	According to Gordon's map.
	Shongum, Randolph Township.	On Den Brook, below Shongum, Gordon has 2 forges.
	N. Branch of Raritan, Mendham Township.	1850.
Budd's, ...	Hacklebarney, Chester Township.	
Budd's, ...	Black River, Chester Township.	
Welsh's, ...	One mile below Bartleyville, Mt. Olive Township.	
Bartleyville, ...	Bartleyville, Mount Olive Township.	1790.
Mount Olive or Stephen's, ...	One mile below Bartleyville, Mt. Olive Township.	
Shippenport, ...	Shippenport, Roxbury Township.	1843.

OCEAN COUNTY.

Three Partners, ...	Near Bricksburg.	According to Gordon.
Butcher's Works, ...	Near Burrsville.	
	Dover.	In operation 1866-7.
	Ferrago.	Stopped in 1851.
	Westecunk (West Creek).	

PASSAIC COUNTY.

Clinton, ...	West Milford Township.	
Stockholm, ...	West Milford Township.	At and near Stockholm there were 4 forges.

Name.	*Location.*	*Remarks.*
Charlottesburg,	Charlottesburg, West Milford Township.	Built in 1840.
	Pequannock Valley, West Milford Township.	There were 2 forges between Charlottesburg and Smith's, in the time of the London Co.
Smith's,	Smith's Mills, West Milford Township.	
Vreeland's	One mile west of Bloomingdale.	
Ryerson's,	Bloomingdale.	Built in 1840.
Lond Pond,	Ringwood Works.	Built by Hasenclever, 1764-67.
	Ringwood Works.	Three forges were built by Hasenclever in 1764.
	Boardville.	
	Wynokie.	

SUSSEX COUNTY.

	Canistear, Vernon Township.	1796.
	Franklin, Hardiston Township.	
	Windham, Hardiston Township.	Built about 1790.
	Sparta, Sparta Township.	Two forges, 1821-3.
Morris Anchor W'ks,	Norman's Pond, Sparta Township.	Two forges, 1821-3.
Hopewell,	Hopewell, Sparta Township.	1780.
Columbia,	Byram Township.	1800.
Roseville,	Byram Township.	1828.
Lockwood,	Byram Township.	1857.
Andover,	Byram Township.	1804.
Stanhope,	Byram Township.	

Table II.—List of Charcoal Blast Furnaces Formerly Operated in New Jersey.

ATLANTIC COUNTY.

Gloucester,	Mullica Township.	
Weymouth,	Hamilton Township.	Idle since 1854.
Etna,	Weymouth Township.	

BURLINGTON COUNTY.

Hanover,	Hanover.	Idle since 1854.
Mount Holly,	Mount Holly.	Mentioned by Acrelius in 1759.
Mary Ann,	Pemberton Township.	
Union Works,	Woodland Township.	

Name.	*Location.*	*Remarks.*
Speedwell, ...	Woodland Township.	
Hampton, ...	Shamong Township.	
Atsion, ...	Shamong Township.	
Batsto, ...	Washington Township.	Built in 1766; ran until 1855.
Martha, ...		
Taunton, ...	Medford Township.	
	CAPE MAY COUNTY.	
Tuckahoe, ...	Tuckahoe.	
	CUMBERLAND COUNTY.	
Cumberland, ...	Manumuskin.	Out of blast since 1844.
Millville, ...	Millville.	Built 1815; out of blast since 1855.
Bridgeton, ...	Bridgeton.	
	HUNTERDON COUNTY.	
Union, ...	Near High Bridge.	In existence in 1759; abandoned in 1778, and a ruin.
Amesbury, ...	Near High Bridge.	1755 (?) in ruins.
	MONMOUTH COUNTY.	
Morris Iron Works,.	Tinton Falls.	At work in 1682.
Howell, ...	Manasquan River.	
	MORRIS COUNTY.	
Mount Hope, ...	Mount Hope.	1772.
Splitrock, ...	Splitrock, Rockaway Township.	
Hibernia, ...	Hibernia, Rockaway Township.	Built before 1764.
	Old Boonton, Hanover Township.	
	OCEAN COUNTY.	
Bergen Iron Works,.	Bricksburg.	
Dover, ...	Manchester.	
Phœnix, ...	One mile east of Manchester.	In ruins (Gordon's map).
	PASSAIC COUNTY.	
Clinton, ...	West Milford Township.	Stopped in 1849; in ruins.

Name.	*Location.*	*Remarks.*
Long Pond, ...	Ringwood Works.	Built in 1764-7; rebuilt as an anthracite furnace.
Ringwood, ...	Ringwood.	Built in 1764-7; a ruin.
Freedom, ...	Wynokie Valley.	1838; out of blast in 1855 and down.
Pompton, ...	Pompton.	1837.
Ryerson's, ...	Bloomingdale.	In ruins.
Charlottesburg, ...	Charlottesburg.	1767; was abandoned 1772.

SUSSEX COUNTY.

Wawayanda, ...	Vernon Township.	Built in 1845; out of blast since 1856.
Hamburgh, ...	Hamburgh.	
Franklin, ...	Franklin.	Built in 1770; last repaired in 1854. Rebuilt as anthracite furnace.
Ogden's, ...	Ogdensburg.	In existence before 1759.
Andover, ...	Andover.	Built in 1763.

WARREN COUNTY.

	Changewater.	
Oxford, ...	Oxford.	Built in 1742-3; rebuilt as an anthracite furnace.

Table III.—Anthracite Blast Furnaces in New Jersey.

HUDSON COUNTY.

Secaucus Iron Wks.,	.Secaucus.	Active in 1907.
Furnace of New Jersey Zinc Company,.	Newark.	

MORRIS COUNTY.

Chester, ...	Chester.	
Port Oram, ...	Wharton.	Active in 1907.
Boonton Iron Wks.,	.Boonton.	

PASSAIC COUNTY.

Ringwood Iron Wks.,	Ringwood.	

SUSSEX COUNTY.

Name.	*Location.*	*Remarks.*
Furnace of New Jersey Zinc Company,	Franklin.	
Musconetcong Iron Works,	Stanhope.	Active in 1907.

WARREN COUNTY.

Warren,	Hackettstown.	
Pequest,	Oxford Township.	Active in 1907.
Oxford Furnace,	Oxford Furnace.	Active in 1905.
Phillipsburg,	Phillipsburg.	Active in 1907.

The amount of ore furnished to the forges and the early furnaces was not large, because the demand for the iron made was mainly for local consumption. In 1821 Morse's Gazetteer reports the manufacture of 2,500 tons of iron. In 1831 the product had reached 4,671 tons annually, all of it, of course, being reduced by charcoal.

As soon as anthracite furnaces came into use the furnace business began to increase rapidly and with it there was a great increase in the quantity of ore produced. In 1855 according to Dr. Kitchell's estimate the amount of ore mined in Northern New Jersey was about 100,000 tons. This was more than doubled by 1864 and reached 275,000 tons in 1867.

In the report of 1868 the list of mines given contained the names of 115 separate operations. During 1870 and 1871 there were many explorations in Sussex and Warren counties. These increased the number of named ore occurrences to 161 in the latter year. Many of these were explorations only, and some of the mines working in 1868 had in the meanwhile been closed so that the actual number from which ore was being raised in 1871 was less than in 1868. The greater portion of the ore shipped at this time was obtained from about 30 mines, the balance being explorations mainly. The active mines were being worked more vigorously than heretofore, however, the yield being about 450,000 tons. In the following year the yield was increased to about 600,000 tons, the Kishpaugh, the Howell and other mines on Jenny Jump Mountain having added their quota

to the product of the older mines. In 1873 there was an increase of only 65,000 tons over the preceding year. This small increase was the result of the financial depression that began then to be apparent, and which necessitated the closing down of some of the furnaces. The list of active mines and promising explorations given in the Report of the State Geologist for this year contained 203 names of mines, and of these 61 mines were reported as working.

The financial depression of 1873 continued through several years, its effect being noticed in a reduction of the output to 525,075 tons in 1874, a falling off of 125,000 tons from the preceding year. The number of mines enumerated in the Survey's list for this year is 225, of which 10 were new. Of the latter, four contributed to the output during the year. In 1875 several of the larger mines suspended operation, and most of the smaller ones, the production being diminished to 390,000 tons. The few mines producing Bessemer ore continued to work, however, and there was some examination of old properties with the hope of adding to the number of mines producing this class of ore for which there was considerable demand because of the fact that steel pig had been made from New Jersey magnetites by several furnaces in 1875. During the following year there was a further reduction in the output of ore amounting to 105,000 tons, but in the succeeding year (1877) there was a slight increase. These were the two leanest years in the quarter century between 1869 and 1894. During this period only 30 mines continued to operate.

From 1877 to 1882 there was a rapid increase in the quantity of ore shipped, the maximum year's output for the State being reached in the latter year when the yield rose to nearly a million tons (932,762). In 1879 it is reported that there were 16 blast furnaces in the State run largely upon home ores. During the preceding period of depression the mine operators had been compelled to the utmost economy in mining the ore. The lessons thus learned were not forgotten during the more prosperous years that followed, so that in spite of the low price at which the ore had to be sold as compared with the prices brought prior to the panic and in spite of the further fact that the ore had now to meet the competition of the rich hematites of the Lake Superior

region, the mine operators, as the result of the economies forced upon them, were able to increase their output. Moreover, the more prosperous condition of the trade caused the starting up of many old mines and gave a great impetus to the work of exploration. This is seen in the statistics of the State Survey. In the report of 1879 there were 300 mines mentioned of which 8 were new openings. The balance were old mines, the increase in the number over that in earlier reports being explained by the fact that in the early reports groups of mines under one management were entered under one name, while in the report of 1879 they were mentioned separately. The increase in the prosperity of the mining community was reflected particularly in the great increase in the number of active mines, of which 50 were reported. Many of these, however, were not properly situated for economical production and consequently in the succeeding year some of them were closed down. The number of mines worked during some part of the year 1880 was 136, while those operating at the close of the year numbered only 81. The total number of mine names given in the list for that year was 350. The gain over the preceding year was partly due to the listing of a few old mines that had not been noted previously and to the discovery and opening of a few new ones.

In the census report of 1880 most of the mines producing during the year from July 1st, 1879, to June 31st, 1880, were visited and estimates of their yield obtained. Since this is the longest list of active New Jersey mines ever reported, and since it in some measure indicates the possibilities of ore production from localities at present abandoned, it is reproduced below. While some of the large producers of this time are still actively operated, others of them have probably been abandoned permanently. The large number of small producers in the list, however, is promising as indicating that there is still a great reserve of ore waiting to be removed when the conditions are more favorable for the working of small deposits than at present.

Table IV.—List of Mines Producing Magnetic Ore in the Census Year 1879–1880.

Mine.	*Tons.*
Allen,	10,130
Annandale,	625
Andover and Sulphur Hill,	15,201
Bald Pate,	150
Baker,	14,695
Barker,	200
Beach Glen,	9,486
Beers,	22
Black Hills,	2,195
Brotherton,	4,730
Brown,	1,232
Bryant,	6,720
Budd,	2,016
Butler,	280
Byram,	16,605
Canistear (1879),	10,000
Centennial,	
Charlottesburg,	3,920
Combs,	4,480
Cobb,	1,288
Cooper (at Chester),	5,860
Cregan,	250
Dalrymple,	2,650
Davenport,	1,120
Day,	20
Dickerson,	28,900
Dodge,	358
De Bow,	112
Eveland,	224
Ford,	17,580
Evers,	2,500
Gove,	3,920
Gray,	1,940
Green Pond,	18,053
Hacklebarney,	31,000
Hager,	800
Hann,	150
Hude,	2,887
Huff,	5,015
Hurd,	11,200
Hurdtown,	29,232
Hibernia, Willis,	10,975
Hibernia, Glendon,	85,622
Hibernia, Lower Wood,	41,576
High Bridge,	2,000
High Ledge,	1,120
Hill,	6,720
Kahart,	50
Kane,	250
King,	280
King (at Mine Hill),	2,560
Kishpaugh,	12,710
Large,	100
McKean,	224
Millen,	1,263
Montauk,	357
Mt. Hope,	50,379
Mt. Olive,	1,625
Mt. Pleasant,	22,525
Oxford,	22,359
Orchard,	14,000
Ogden, Davenport,	1,120
Ogden, Old Ogden,	2,464
Ogden, Roberts,	16,800
Ogden, Pardee,	8,089
Pidcock,	156
Pikes Peak,	8,960
Pitney,	2,800
Randall,	8,360
Richard,	35,463
Ringwood,	26,482
Rockaway Valley,	500
Roseville,	1,347
Samson,	3,360
Scrub Oak,	1,680
Sickles,	1,000
Skellinger,	4,480
Split-Rock Pond,	560
Sterling,	16,800
Stony Brook,	100
Stoutenburgh,	1,680
Teabo,	22,468
Topping,	875
Washington Forge,	2,721
Weldon,	1,276
West End,	11,086
Willever & Godfrey,	500
Wright,	12

Mine.	Tons.	Mine.	Tons.
Asbury,		Hoagland,	
Case (25),		Pequest,	
Mayberry (300),	500	Roseberry,	950
Petty (40),		Schuler,	
Rodenburg,		Lawrence,	760
		De Hart,	
		Total,	727,790

Table V.—List of Mines Producing Limonite Ore in the Census Year 1879–1880.

Mine.	Tons.	Mine.	Tons.
Brown,	434	Roseberry,	500
Dafford,	500	Thomas,	2,050
Neighbor,	896	Wean,	565
New Village,	374	Wm. Hamlen,	344
Shields,	9,870		
Radley,	78	Total,	16,003
Rapp,	392		

In the succeeding two years there were a few additional mines opened, but the great gain in production was the result of the more vigorous working of the larger mines controlled by furnace companies. In 1882 the market for ore began to contract and as a consequence during its latter part some of the mines that had contributed to the production during the earlier portion of the year were compelled to shut down. Moreover, about this time steel was beginning to replace iron for many of the uses to which this commodity had hitherto been applied and as a result the iron-making ores to which class the majority of the New Jersey ores belong, began to meet with slow sales. The replacement of iron by steel at this time was due largely to the utilization of the Lake Superior ores, which are so rich and so well adapted to steel making that the cost of manufacture of this metal had been so far reduced as to make it a strong competitor for many purposes with the hitherto cheaper iron. At this time also some of the older and larger mines of the State had become very deep, and the expense of raising ore had consequently increased to such an extent that it could no longer be produced at a profit on a falling market. Among the mines then abandoned were the Byram, Randall Hill, and Swedes. Many of the smaller mines which

were at a considerable distance from the railroad were also closed down, mainly, however, because the price obtained for their ore was not sufficient to pay the cost of its transportation to the railroads. In spite of the closing of these mines during the latter part of the year and the consequent loss of their contribution to the year's production the aggregate for the year was 932,762 tons, the largest total ever raised from New Jersey mines in a single calendar year. In the following year, however, the full effect of the adverse conditions was felt. The production fell off to 521,416 tons. Nearly all the smaller mines were closed, some being abandoned permanently. Only the more thoroughly equipped mines that were near transportation lines continued in operation. Prospecting ceased. There was no stimulus to exploration, as it was recognized that new mines in localities distant from the railroads would not be able to produce ore at a profit.

In the next succeeding years the same conditions prevailed, the output continued to decline and the trade languished until in 1885 it reached a very low ebb, only 350,000 tons being produced. Only the very largest mines continued in operation, 30 being the number mentioned in the State reports as having been worked during some portion of the year.

In 1886 the price of ore improved slightly. The mines immediately responded to the demands of the market and increased their output to 500,501 tons. The increase in production was, however, not due to an increase in the number of mines worked but rather to the more energetic operation of those that had continued to run during the dull times of the preceding two years. The number indicated in the State report of 1886 as having been in operation during the year was 33. The conditions remained quiescent during the next twelve-month and the yield of ore was approximately the same as in the preceding year (547,889). In 1888, however, there was a loss of 100,000 tons, the production for this year being only 447,738 tons.

From this time to 1891 there was a small but steady improvement in the ore trade, the output gradually mounting to 551,358 tons in the latter year. There was a slow decrease in the number of mines engaged in raising ore, but a considerable increase in

the yield of the most active mines. In 1891, for instance, four mines produced an aggregate output of 316,248 tons of ore, or nearly 60 per cent. of that of the State.

There was a strong tendency about this time to the concentration of production at a few centers convenient to railroad lines. In other words, as the market price of ore diminished the cost of transporting it to the furnace became a more and more influential factor in determining the mines that could be successfully worked. The abandonment of mines at this time was not necessarily the result of the exhaustion of their ore bodies, but was rather because of their inability to deliver ore to the furnaces at a profit in competition with mines that were more favorably situated with respect to transportation. It is encouraging to note that the producing mines were mostly the old historic ones whose periods of activity reach back a half century or more. At this time, however, two of the old mines, the Teabo and the Dickerson, were closed down, because the depth of profitable mining under conditions then prevailing had been reached. Both of these mines had had honorable careers and had contributed very largely to the output of the State, the Dickerson having produced an aggregate of about 1,000,000 tons. In 1905 the Dickerson was reopened, but not in the same deposits that had formerly been so productive.

The number of active mines continued to diminish after 1891, and also the State's output of ore, until in 1897 it reached its lowest ebb in recent years, viz., 257,235 tons. The low price of ore, which was due to the general business depression throughout the country at this period, together with the great increase in the use of Lake Superior ores in Eastern furnaces, had seriously affected the New Jersey ore business, and it was only in consequence of the consolidation effected between mines and furnaces that any of the mines were able to dispose of their output. The improvement in mining methods and machinery rendered imperative by the necessity for producing ore cheaply showed their effect, however, in the ability of the New Jersey mines to market ores in the Lehigh Valley at a lower price per unit of iron than any competing district. In the year 1896 only the mines at Hibernia, Wharton and Hurdtown continued at work. Prac-

tically all the mines that remained active during the succeeding years were operated by the owners of furnaces.

In 1898 the tide turned. By this time the large economies that had been introduced in the method of working the great hematite deposits in the lake region and the low freights granted to lake shippers resulted in the lowering of the price of lake ore to such an extent that the New Jersey ore had to be sold at about $2.00 per ton in order to secure purchasers. At this price only a few of the most favorably situated mines could continue operations, but these were able to compete with the rich lake hematites, and when the demand for ore increased, as it did in the last years of the century, they showed themselves capable of meeting this demand by largely increasing their output. The Hurdtown mine was closed in 1898. It had at this time reached a depth of 6,000 feet on the slope, or 2,600 feet vertically, and was at that time the deepest mine in the State. In this same year, however, the concentrating works at Edison, which had been erected to concentrate the low-grade ores of the old mines near Ogdensburg, were put into operation, their yield about compensating for the loss due to the closing of the Hurdtown mine.

With the rapid rise of the price of iron in the opening month of the year 1899, there followed a rise in the value of ore. The New Jersey mines quickly responded by raising their output to 300,757 tons. The older mines increased their production, several enterprises that had been closed by low prices resumed operations, many leases of mining properties were made, and several sales of ore lands were consummated. Among the mines that were reopened were the Green Pond, Beach Glen, Ford, Weldon and Kishpaugh mines, and the groups at Ringwood, Oxford and Mount Hope. With the advent of more remunerative prices, improvement in mining plants were pushed forward with vigor, concentrating works were constructed and much lean ore was made marketable. Henceforth concentrates became a prominent feature of the New Jersey ore market, thus enabling the poorer ores of some of the more favorably situated mines to be delivered at the furnaces in such condition and at such prices as to prevent richer ores from mines less favorably situated from competing with them.

The "boom" of 1899 continued well into 1900, but during the later months of this year it collapsed. Furnaces were shut down, the demand for ore ceased and as a consequence some of the mines that had been reopened in 1899 were compelled to close again. In all, 15 mines were in operation during the year; but two of these were shut down before its close. Because of the activity in the early part of the year the output was increased over 1899 by 41,633 tons. The depression was only temporary, however, for the following year saw another increase in the output to 401,151 tons, an increase in the number of operating mines, and an increase in the output of the individual mines.

During 1903 the ore market again took a downward turn. Each recurring depression finds the mines deeper and the cost of raising ore tending to become greater. But few of the mines in the State had been worked with regard to the future and in most mines no pains had been taken to compensate for the increasing depth by improvements in the mining plant. Only those mines that were sure of their markets, *i. e.*, those that were operated in connection with furnaces, made investments in the shape of permanent improvements. The year 1903, therefore, saw all the independent mines closed down and only those in operation that were run in direct connection with blast furnaces. Since the demand of the furnaces was comparatively slight the mines were run at a moderate rate. Fortunately, however, the progressive policy of the furnacemen had by this time gotten their mines into good shape, and in excellent condition to respond promptly to the demand for ore, so that when the demand came in the following years the mines were able to furnish the product, which in 1906 amounted to 542,488 tons, obtained from eight mining centers, and in 1907 to 558,137 tons, obtained from 17 mines at twelve mining centers.

The present year (1909) finds the ore-mining industry in a very favorable condition in respect to equipment. There are but 13 mines working, but these are operated with modern equipment, which enables them to earn a profit even when the selling price of ore is considerably less than was the cost of mining it a few years ago. Moreover several old mines are being re-opened in the hope that they may be made to yield sufficient ore of good

quality under modern conditions of mining to warrant their successful operation. No ore need now be raised at a loss, since there is no clamoring on the part of the mine-owners for a disposal of the ore. The policy of husbanding their resources until such time as ore is needed will be followed. There will naturally be wide and sudden fluctuations in the output from year to year, because of the enforcement of the law of supply and demand. The reserves of ore in the operating mines are still large, so that there is no fear of the early exhaustion of the ore bodies, and besides, if iron ore ever becomes so scarce elsewhere that the New Jersey magnetites will command a price as great as that obtained a decade or more ago there are hundreds of now-abandoned mines which may be opened up again and made to supply a large quantity of ore for an indeterminate period.

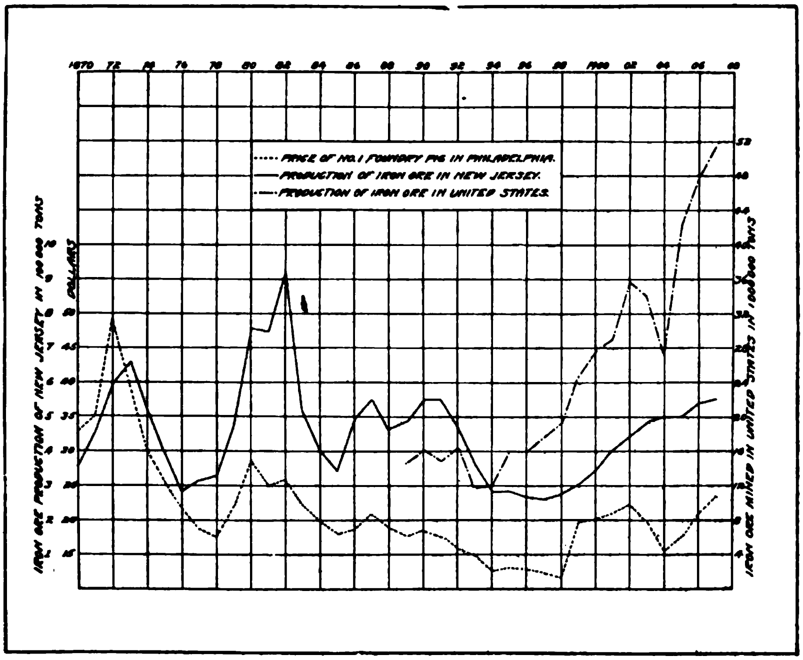

Fig. 1.

Diagram showing the production of iron ore in New Jersey from 1870–1908, in the U. S., 1889–1908, and the price of foundry pig in Philadelphia, 1870–1908.

The yield of the State during the past century is shown in the table below, which is essentially that printed in the Annual Report of the State Geologist of New Jersey for the year 1908. It is estimated that the total yield of the State since the beginning is in the neighborhood of 22,000,000 tons. The fluctuation in the amount of ore produced in recent years is graphically represented in figure 1.

Table VI.—Production of Iron Ore in New Jersey, 1790–1908.

Year.	*Iron Ore.*	*Authority.*
1790,	10,000 tons,	Morse's estimate.
1830,	20,000 tons.	Gordon's Gazetteer.
1855,	100,000 tons,	Dr. Kitchell's estimate.
1860,	164,900 tons,	United States census.
1864,	226,000 tons,	Annual Report State Geologist.
1867,	275,067 tons,	Annual Report State Geologist.
1870,	362,636 tons,	United States census.
1871,	450,000 tons,	Annual Report State Geologist.
1872,	600,000 tons,	Annual Report State Geologist.
1873,	665,000 tons,	Annual Report State Geologist.
1874,	525,000 tons,	Annual Report State Geologist.
1875,	390,000 tons,	Annual Report State Geologist.
1876,	285,000 tons,	Annual Report State Geologist.
1877,	315,000 tons,	Annual Report State Geologist.
1878,	409,674 tons,	Annual Report State Geologist.
1879,	488,028 tons,	Annual Report State Geologist.
1880,	745,000 tons,	Annual Report State Geologist.
1881,	737,052 tons,	Annual Report State Geologist.
1882,	932,762 tons,	Annual Report State Geologist.
1884,	393,710 tons,	Annual Report State Geologist.
1885,	330,000 tons,	Annual Report State Geologist.
1886,	500,501 tons,	Annual Report State Geologist.
1887,	547,889 tons,	Annual Report State Geologist.
1888.	447,738 tons,	Annual Report State Geologist.
1889,	482,109 tons,	Annual Report State Geologist
1890,	552,996 tons,	Annual Report State Geologist.
1891,	551,358 tons,	Annual Report State Geologist.
1892,	465,455 tons,	Annual Report State Geologist.
1893,	356,150 tons,	Annual Report State Geologist.
1894,	277,483 tons,	Annual Report State Geologist.
1895,	282,433 tons,	Annual Report State Geologist.
1896,	264,999 tons,	Annual Report State Geologist.
1897,	257,235 tons,	Annual Report State Geologist.
1898,	275,378 tons,	Annual Report State Geologist.
1899,	300,757 tons,	Annual Report State Geologist.
1900,	342,390 tons,[1]	Annual Report State Geologist.

Year.	*Iron Ore.*	*Authority.*
1901.	401,151 tons,	Annual Report State Geologist.
1902,	443,728 tons,	Annual Report State Geologist.
1903,	484,796 tons,[1]	Annual Report State Geologist.
1904,	499,952 tons,	Annual Report State Geologist.
1905,	500,541 tons,	Annual Report State Geologist.
1906,	542,488 tons,	Annual Report State Geologist.
1907,	558,137 tons,	Annual Report State Geologist.
1908,	432,566 tons,	Annual Report State Geologist.

OUTLINE OF THE GEOLOGY OF NEW JERSEY.

The rocks exposed in New Jersey include those of nearly all geological ages, from the Algonkian to the Pleistocene. They may be grouped as follows:

Table VII.—Classification of New Jersey Rock Formations.

Cenozoic.	Quaternary,	Pleistocene,	Wisconsin drift. Unconformitv. Pre-Wisconsin drift. Unconformity.	Glacial.	Cape May formation. Pensauken formation. Bridgeton formation. — Non-Glacial.
	Tertiary,	Neocene,	Beacon Hill gravels (Lafayette formation?)		
			Cohansey formation. Unconformity. Kirkwood formation. Unconformity.	(Chesapeake formation?)	
		Eocene,	Shark River formation.		
Mesozoic.	Cretaceous,	Rancocas Group,	Manasquan marl. Vincentown marl. Hornerstown marl.		
		Monmouth Group,	Red Bank sand. Navesink marl. Mt. Laurel sand.		
		Matawan Group,	Wenonah sand. Marshalltown clay-marl. Englishtown sand. Woodbury clay. Merchantville clay-marl.		
			Magothy formation (clay, sand and gravel). Unconformity.		
			Raritan formation (clay, sand and gravel). Unconformity.		
	Newark,		Trap sheets (diabase and basalt) at various horizons. Brunswick shales (red shales, sandstones and conglomerates). Lockatong series (shales, argillites and flagstones). Stockton series (arkose sandstones and shales, some conglomerates). Unconformity.		

[1] The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material, which should have been reduced to its equivalent in concentrates. The figures for 1903, given in the report for that year, were incorrect.

PALÆOZOIC	Devonian		Skunnemunk Conglomerate (including red sandstone).
			Bellvale flags (bedded sandstone).
			Pequanac shales.
			Onondaga limestone—Kanouse sandstone (including fine grained conglomerate).
			Esopus grit.
			Oriskany formation.
			Kingston or Port Ewen beds.
			Becraft limestone.
			New Scotland beds.
			Coeymans limestone.
			Stormville sandstone.
	Silurian		Manlius limestone.
			Rondout limestone.
		Salina Group	Decker formation (shaly limestone).
			Bossardville limestone.
			Poxino Island shales.
			High Falls formation—Longwood shales.
			Shawangunk cong.—Green Pond cong.
			Unconformity.
	Ordovician		Martinsburg (Hudson) formation (shales, flagstones, slates and sandstones).
			Jacksonburg (Trenton) limestone (fossiliferous limestone).
	Cambrian		Kittatinny limestone (blue limestone).
			Hardyston quartzite (sandstones and conglomerates).
			Unconformity.
	Algonkian		Gneisses.
			Franklin limestone (including a few conglomerates, quartzites and slates).

The oldest rocks known to occur in New Jersey are regarded as of Algonkian age. The Algonkian series comprises white crystalline limestone, quartzite and quartzose conglomerates, a small quantity of schistose volcanic rocks and great quantities of acid and basic gneisses. These are cut by numerous dikes of pegmatite or coarse granite, and a few small dikes of diabase that are believed to be connected with the great sheets of this rock to the south that were intruded during Newark time. Magnetic ores are associated with the limestone, the pegmatites and the gneisses. Hematites have been found only in the quartzites and quartzose conglomerates.

The Cambrian series is represented in New Jersey by a comparatively thin layer of feldspathic conglomerate and sandstone, which in some places becomes a quartzite. This is believed to be equivalent to the Lower Cambrian sandstone in New York and elsewhere. It is followed by a thick succession of magnesian limestones. The former rock is known as the Hardyston quartzite because its true relation to the underlying Franklin lime-

stone was first revealed by exposures in Hardyston township, in Sussex County.

Between the Algonkian beds and Hardyston quartzite is a great unconformity. The quartzite was laid down upon the eroded surface of the gneisses and the Franklin limestone, and consequently is much younger than these.

Above the Hardyston quartzite follow beds of magnesian limestones, with a few interleaved shales. These have been called the Kittatinny limestone, from the valley in which they are extensively developed. The limestone is known also as the "blue limestone," in contradistinction to the white pre-Cambrian (Franklin) limestone. The underlying quartzite grades upward into the shales, and these into the limestone. The limestone and shales are folded and faulted. In many places they lie immediately upon the Algonkian rocks, the Cambrian quartzite being entirely wanting. In these cases the junction is supposed to be along a fault plane, the quartzite perhaps being beneath the limestone many feet below the present surface.

The limonites (or brown hematite ores) are associated with this limestone, and are usually found near its contact with the underlying gneisses, or with the overlying formations.

Following the Kittatinny limestone upward is a regular succession of limestones, shales and sandstones of Paleozoic age. All are folded and faulted in the same way as is the Kittatinny limestone. Above these is an unconformity, and above this, lying upon the truncated edges of the folded Paleozoic and pre-Paleozoic rocks, is a gently inclined series of younger rocks. The latter need not be considered here, as there are no iron ores associated with them, except the bog ores that may occur on the surface wherever the conditions of deposition are favorable.

The folding of the Paleozoic beds took place just before the time represented by the unconformity at their top, which separates the Paleozoic rocks from the succeeding Mesozoic ones. This folding affected all Paleozoic and Algonkian rocks in the eastern part of the United States, and resulted in the making of the Appalachian Mountains. It was during this period of deformation that the limestones and other rocks in the valleys between the Highland ridges were folded. At least the greater

portion of the folding was produced at this time. At the same time, perhaps, the rocks of the ridges may also have been compressed to some extent. The principal compression of these, however, must have occurred before the Hardyston quartzite was laid down, *i. e.*, in pre-Paleozoic time, since boulders of well-defined gneisses are common in the conglomerates at the base of the quartzite.

At the opening of Mesozoic time the land which is now northern New Jersey was somewhat above its present height. The weather then began to break down the rocks and the streams to carry away the debris. The two agencies acting together reduced the country until it became a gently rolling plain, sloping gradually oceanward.

During this period of denudation, *i. e.*, during the time when the folded Paleozoic rocks were being reduced to near sea-level, the Newark deposits were being laid down on a plain that extended eastward from the base of the mountains by a system of great rivers which deposited silts, sand and pebbles, that later became shales, sandstones and conglomerates. The deposits of neighboring rivers coalesced, forming a general covering over the plain's surface. The plain, together with its veneer of sediments, later became deformed. By folding and faulting, troughs were produced, running parallel to the trend of the mountain ridges. The deposits of Newark time were carried downward in some places and raised in others. Subsequently (in early Cretaceous time) the deformed surface was again eroded and a new plain was formed. The Newark rocks that were in the troughs were protected, while those in the saddles between the troughs were worn away. Thus on the new plain the Newark rocks were left in long, narrow belts running southwest and northeast. The trap rocks that are associated with the Newark sediments were partly lava that flowed out on the surface of the beds, and partly sheets of rock that were forced between their lower layers.

The new plain carved from the folded rocks of the old plain extended north and south over a wide area, and was at one time very near the sea-level. It was afterward elevated, its remnants, in some places now 1400 feet above the original position, being recognizable in the flat tops of the Highland ridges, and of some

of the trap ridges rising above the general level of the lowland that stretches southward from the base of the Highlands. The tops of these elevations, considered as a whole, form a sloping surface inclining seaward about 70 feet to the mile.

After this elevation the denudation processes again became exceedingly active. The relatively soft and easily erodible limestones that had been folded between the gneisses, and the shales that surrounded the trap masses were worn away more rapidly than the resistant crystalline rocks, and in this way the present valleys were developed between ridges.

While this was going on the southern and central portions of the State oscillated below and above sea level through a long series of changes, and during later Mesozoic and Tertiary time a great succession of sands, marls and clays were deposited. These were finally raised above the ocean to form the southern part of the State. They are strongly contrasted with the older rocks in their attitudes. The former are folded or tilted, while the latter are uniformly flat, or but slightly inclined toward the sea. During the later stages of the history glaciers from the north covered the northern part of the State with a series of loose deposits, which determined the minor features of its topography.

GENERAL CHARACTER OF THE IRON ORES.

The iron ores that have been mined in New Jersey are bog ores, limonite or brown hematite, red hematite, and magnetite. In the early years of the State's mining history considerable bog ore was utilized in the manufacture of bloomery iron. Later, the limonites became of considerable importance. At present magnetites are mined almost exclusively, although in the last two years progress has been reported in the redevelopment of two of the large limonite mines[1] that were formerly of considerable importance. Hematite has never been mined to any great extent unless the ore from the Andover mine was of this character. In any event, the quantity of hematite taken from the ground is small as compared with the immense aggregate of magnetite

[1] Work at one of these has since been suspended (June, 1910). H. B. K.

that has been mined and is much less in quantity than the amount of limonite raised.

Magnetite has always been the important ore. It has been mined from the earliest period, and at the time of the Revolution in 1776, magnetite mining already occupied an important place among the State's industries. No records are at hand that enable one to judge of the relative importance of the several ores at different periods in the mining history of the State, the only records of value in this respect being those of the Tenth Census. In the report of this Census it is estimated that in the twelve months between July 1, 1879, and June 30, 1880, there were raised about 728,000 tons of magnetite and about 16,000 tons of limonite. In this year, however, the limonite mines were more energetically worked than usual and, as a consequence, limonite makes a better percentage showing than would be the case if the record covered a longer period. In 1830 it is estimated that 2,000 tons of ore were mined and it is thought that most of this was bog ore.

In spite of the slight importance now credited to limonite and bog ore it is possible that these ores may in the future become valuable sources of the metal, and it is interesting, therefore, to know that there are still reserves of these materials in the ground awaiting utilization.

The geological associations of the four ores are as different as their physical and chemical characteristics. The bog ore is found mainly as surface accumulations in bogs and swampy places, the limonites are in the Kittatinny limestone and in one or two places in later sediments; the magnetites, in the Algonkian gneisses and crystalline limestone; and the hematite, in the silicious sedimentary rocks associated with the Franklin limestone.

Each of the ores is discussed in some detail in the following pages. The magnetites because of their overshadowing importance are discussed at much greater length than the other ores. The hematites are treated very briefly for the reason that information concerning them is very meager.

CHAPTER II.

THE BOG IRON ORES.

CONTENTS.

GENERAL DISCUSSION.

NATURE OF THE ORE.

Appearance.—The bog iron ores are mixtures of limonite and other hydrated oxides of iron intermingled with clay, sand and various organic compounds. As usually found, the ore is a brown yellowish-red, soft, earthy substance, containing scattered nodules of compact limonite, casts of leaves, roots, etc., composed of the same material and mixed with sand or clay, the whole forming thin layers that may or may not be porous. It occurs, also, as crusts enveloping twigs, leaves, bones, and other organic remains. When dried the ore tends to fall into a brown or reddish powder.

Chemical Composition.—Since bog ore consists essentially of limonite, its composition is that of an impure limonite, $Fe_4O_3(OH)_6$. When comparatively free from impurities the per-

centage of iron in the dry ore may reach 59.89%, but this high percentage is rarely reached because of the great quantity of foreign matter mixed with the limonite. Usually the ore contains not more than 30% of iron in its natural state, the remainder consisting of clay, sand, water, and organic acids. The phosphorus content is nearly always high, some of the element being present as the iron phosphate, vivianite ($Fe_3(PO_4)_2+8H_2O$). Sulphur is also nearly always present in large quantities. These two elements are constituents of the organic matter to whose decomposition the ores owe, in part, their existence. They are also sometimes due to the minerals that constitute the source of the ferruginous solutions from which the ore was deposited.

Complete analyses of the bog irons of New Jersey have not been published, though many of them must have been made in connection with the smelting of the ores in early times. Determinations of the metallic contents of a few of them are given in the table below. It is probable that they are not of equal value. Some were unquestionably made on material dried at 212°, while others were probably made on air-dried specimens, and others, perhaps, on material in its natural condition, *i. e.,* as obtained from the mine. There is, however, nothing in the reports of the analyses to indicate the nature of the treatment to which the samples were subjected.

Table VIII.—Iron Contents of New Jersey Bog Ores.

	Fe.	*P.*	*S.*	*Authority.*[1]
Menlo Park, Middlesex Co., ...	12.15%	...	...	N. J., 1877, p. 49
Jacksonville, Middlesex Co., ...	57.06%	.047	.288	N. J., 1880, p. 178
Gulick Mine, Middlesex Co., ...	49.95%	.12	...	N. J., 1880, p. 130
Atsion Iron Works, Burlington Co.,..	45.83%	...	...	N. J., 1868, p. 668
Atsion Iron Works, Burlington Co.,..	47.71%	...	...	Ib.
Upper Squankum, Burlington Co., ...	52.94%	...	...	Ib.
Shrewsbury River, Burlington Co., ..	46.98%	...	...	Ib.
Ayers Farm, Allamuchy, Warren Co.,	44.00%	...	...	N. J., 1874, p. 59
Hainesburg, Warren Co., ...	32.00%	...	...	N. J., 1877, p. 49

Metallurgical Value.—Bog ores are but little used at present because of their impurity and the consequent low percentage of

[1] The citation N. J. always refers to the Annual Reports of the State Geologist.

metal they contain. The high percentage of sulphur and phosphorus in them make them unavailable as mixtures for the manufacture of Bessemer iron. In a few places, however, the ore is sufficiently pure and in large enough quantity to be of commercial value. The latter condition is especially true of deposits situated at a distance from hematite and magnetite deposits, and in places where, because of a long haul, the purer ores are too expensive to compete with the less valuable ores in the manufacture of cheap iron.

In this State the bog ores are now of very little economic value. In the early years of the iron industry, however, they were the source of much of the iron forged in the southern part of the State. Professor Cook, in the New Jersey report of 1868, quoting Gordon, states that in 1830 there were 14 furnaces and the same number of forges dependent mainly upon bog iron for their supply of ore. As early as 1868, however, they had all been abandoned. The magnetites had already gained the ascendency as the cheapest source of iron, and the smelting industry in the southern portion of the State succumbed to that in the Highlands.

Even in the early days the bog ore was probably rarely used alone, for we find Cleveland[1] stating on the authority of Conrad and Woodbridge that it was often mixed with other kinds of ore brought down the Delaware from Easton.

During the last half century the large deposits of the ore known to exist in the marshy portions of the state have lain neglected. Within recent years, however, the ore has met with some favor as a road metal—a use to which it is well adapted when properly mixed with sand.

MANNER OF OCCURRENCE.

The bog ores, as their name indicates, are found in bogs and swamps, often immediately under the grass roots, and also in the bottoms of shallow lakes into which swamp waters drain.

[1] An Elementary Treatise on Mineralogy and Geology, etc., Boston, 1816, p. 500.

In New Jersey they are found mainly in the southern portion of the State where the surface is low and the drainage mature, where swamps abound and streams are sluggish. Deposits of considerable size occur also in many flat areas between ridges in its northern portion.

ORIGIN.

Bog ores are formed wherever iron-bearing solutions are exposed to the action of the atmosphere. The swamps are settling basins into which drain the higher lands surrounding them. Consequently, where ferruginous solutions are provided by the rocks of the drainage area, the swamps between the higher lands are natural precipitation basins for iron hydrates.

In New Jersey as elsewhere the bog ores are the result of two processes. Rain water and water which has traversed limestone contain carbonic acid. This dissolves the iron-bearing components of the surface rocks forming dilute chalybeate solutions which flow down into the swamps through rivulets and springs, spread out and thus expose large surfaces to the action of the air. Here the excess of carbon dioxide escapes into the atmosphere, the iron carbonate becomes insoluble and forms a scum, which in contact with the air changes into hydrated iron oxide and finally sinks to the bottom and becomes the ore. Likewise other salts, such as the sulphate derived by the oxidation of pyrite, in meeting alkaline carbonates, as for instance the calcium carbonate dissolved from limestone by underground waters, pass into the carbonate and this, on exposure to the air is oxidized to the hydrate.

$$4\ FeCO_3+O_2+3HO_2=Fe_4O_3(OH)_6+4CO_2$$

On the other hand when decomposing organic matter is exposed to the action of the air, organic acids and carbon dioxide are produced. The former decompose the iron-bearing compounds, forming carbonates that dissolve in the carbonic acid, producing solutions which, when subjected to the conditions outlined above, naturally behave like ferruginous solutions produced in any other way and yield limonite.

The insoluble oxides thus precipitated form a layer to which are added other layers in succession, since the process continues so long as ferruginous solutions are provided. When the drainage is into swamps vegetable matter is carried down with the iron compounds and the two kinds of material are more or less thoroughly mixed. When shallow ponds receive the drainage the hydroxides fall to the bottom and become consolidated into nodules. These are composed of purer material than the deposits in swamps. They may be dredged and used as ore. Moreover, since the process is a continuous one the dredging may be repeated from time to time with success. In some parts of Sweden certain lakes have been worked for ore of this kind during generations at intervals of about 30 years and at each dredging have supplied profitable yields because of the great rapidity with which the removed deposits are renewed.

The principal sources of the iron in the New Jersey ores are the pyrite and the greensands in the Mesozoic clay and sand that are so abundantly spread over the southern portion of the State. In the northern portion the magnetites, limonites, pyrite and the iron silicates in the crystalline rocks may have furnished some of the iron to the swamps in that quarter; but the quantity was inconsiderable as compared with the quantity furnished to the southern swamps by the components of the Mesozoic rocks. Consequently the largest bog ore deposits are found in the south.

DISTRIBUTION AND DESCRIPTION OF DEPOSITS.

If one may judge by the geographical situations of the early furnaces and forges in New Jersey bog ores are very widely distributed throughout the State. Although there are no records by which we are able to discover all the sources of their ores it is evident that these were obtained from many different localities that were widely separated. Since the ores of this class have had no commercial value for some time past, there are no descriptions of recent finds. No search has been made for them in later years, hence we are dependent solely upon the old descriptions for statements of their occurrence.

The largest, and formerly the most important deposits, were in the valley of the Little Egg Harbor River, in Burlington County. These are described by Rogers in his report of 1840 as bordering the principal tributaries of the stream. One tract stretches from the head waters of Atsion Creek in a wide belt southeastward to Landing Creek. The width of the belt is about three miles, and its length about twenty miles. Throughout this area of sixty square miles the ore is found in the stream-beds and alongside all their small branches. The second tract is within the same general district. It occupies a belt along the Tulpehaukin, or Wading River and its branches. It covers quite as extensive an area as the first tract, but the ore deposits are not as abundant. His detailed description of the Atsion deposit will serve as a description of bog ore deposits in general.

"The ores which are used at the Atsion Works are obtained from above the furnace, the present excavations are chiefly at about three or four miles above the pond or dam which supplies the water-power. Great quantities of the ore are also taken from the bed of the pond during the winter, when the furnace is out of blast and the water is drained off. The ores which are used at this furnace are the *loam ore,* the *seed ore,* and the *massive ore.* The swamps of the river (which is rather sluggish) are extensive, and form numerous shallow coves, some of which are covered with water to the depth of about a foot, while others contain a very spongy peat, which is always found on the edges. The ore is chiefly taken from these coves when the water is not too deep, especially along their wet margins. Excavations eight or ten feet square are made, between each of these a thin dike is left, so as to prevent the water from one flowing in upon the workmen in the others. The three kinds of ore are generally found in each hole; the loam ore nearest the surface, the seed ore under this, and the massive ore at the bottom. In some positions, however, only one of these kinds occurs, unaccompanied by the others. In other positions the several varieties may be seen in their various stages of maturity. The loam ore is that which appears to form first, being in reality merely the infiltration of ferruginous sediment into the soil of the bog. This, which is at first quite soft, becomes, by the accumulation of oxides of iron, heavier and more compact. In the center of many lumps, the mass has a crystalline or regular ore-like character. This structure would pervade the whole deposit, could it be exposed for a sufficient length of time to the correcting action. The loam is thus in time completely replaced by the oxide of iron, which is seldom solid, but of a honeycomb structure, the cavities being more or less filled with aluminous matter. These ores are obtained in various conditions of compactness. That which is partly concreted, partly pulverulent or loamy, is called *young ore,* a variety which experience shows to be better adapted for easy fusion than the more concretionary harder kinds.

Great quantities of woody matter, such as stumps and trunks of trees, abound in these ore beds, completely converted into oxide of iron. The curious process of replacement which has taken place, has preserved the precise form and structure of the bark and woody fibre, down to the most delicate lines and markings."[1]

In the northern part of the State another large deposit is reported by Dr. Kitchell as occurring about half a mile southeast of Mount Hope in Rockaway Township, Morris County. It is said to cover an area of 14 or 15 acres with a thickness of one to two feet. A partial analysis of a sample of ore from this deposit indicated the presence of much manganese and some phosphorus, but no sulphur, lime, or magnesia.[2]

Other occurrences of the ore have been noted as follows:

1. One mile north of Dover, along the road to Mount Hope, in Rockaway Township, Morris County.

2. In the meadows east and northeast of Dover, in Rockaway Township, Morris County.

3. On Talman's Creek, a tributary of the Rancocas river in Chester and Evesham townships, Burlington County.

4. On the south branch of the Rancocas River, near its junction with the north branch in Burlington County.

5. On the Manasquan River, near Georgia, in Freehold Township, Monmouth County.

6. On Manalpan and Machaponix creeks, two small tributaries of the South River, in South Amboy Township, Middlesex County.

7. At Menlo Park, in Middlesex County.

8. At the Gulick exploration, half way between Milltown and Dunham's Corners, East Brunswick Township, Middlesex County.

9. At Hainesburg, Warren County.

10. One mile or so northwest of Perrineville, Monmouth County.

11. On the Ayers farm in Allamuchy Township, Warren County.

12. At Jacksonville, in Middlesex County.

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[1] H. D. Rogers: Final Report on the Geology of the State of New Jersey, 1840, p. 298, 299.

[2] Geology of New Jersey, 1856, p. 194.

DESCRIPTION OF INDIVIDUAL MINES.

The Gulick Mine.

The Gulick mine is half way between Milltown and Dunham's Corners, East Brunswick Township, Middlesex County. The ore was found in a nearly horizontal bed about three feet thick, overlain by from one to seven feet of clayey earth. It occurs under a large area which is capable of yielding many tons. The ore contains 49.95% Fe and .12% P. A nearly complete analysis[1] of a sample prepared by taking fragments from forty different lumps gave:

Fe_2O_3	Al_2O_3	MgO	CaO	MnO	SiO_2	TiO_2	P_2O_5	S	H_2O	Total
71.36	2.27	.15	tr	.70	8.90	.00	.27	.00	15.95	=99.60

[1] Annual Report of State Geologist for 1880, p. 129-130.

CHAPTER III.

LIMONITE OR BROWN HEMATITE.

CONTENTS.

Radley mine.
Anderson mine.
Beatyestown mine.
Mines in the German Valley.
Neighbor and Dafford mines.
Mines south of the Highlands.
Bird mine.

GENERAL DISCUSSION.

The ore generally known in New Jersey as hematite is more properly "brown hematite," or *limonite,* a hydrated oxide of iron, differing from "bog iron ore" mainly in its more compact texture, its smaller content of water in its natural state and in its greater purity. Though now mined to a very slight extent, it was formerly an important ore, being much sought for the purpose of mixing with magnetite in the furnaces. While the report of 1868 was being written, it was stated that the supply was insufficient to meet the demand. As the annual capacity of the furnaces working at that time was small, it is probable that the yield of limonite was not more than a few thousand tons. Later, there was a considerable increase in the yield of the ore, the estimate of the product for 1871 being over 15,000 tons, but its occurrence in small and pockety deposits rendered the supply so unsatisfactory to the furnace men, because of their inability to secure steady deliveries of a constant composition, that its use was finally abandoned. Its disuse as a source of the metal was also influenced by the fact that it was neither rich enough nor in sufficiently large quantities to compete with the pure and abundant lake ores that began to find their way into the Eastern markets at about this time.

At present very little limonite of New Jersey origin is being used in the furnaces of the State, its place being taken by the soft hematites imported from New York and Minnesota. There is no question but that if a large quantity of low-phosphorus limonite should be discovered in the future the ore would find a ready sale at remunerative prices. In the neighboring State of Pennsylvania limonites like those of New Jersey are still in use in increasingly large quantities.

NATURE OF THE ORE.

Appearance.—The pure limonite is a compact reddish-brown or black metallic mineral, sometimes occurring in globular, stalactitic or kidneylike masses, with a fibrous structure. More frequently it is found in irregular lumps of a reddish-brown color and a dull luster, or as a red or brown earth, which, when pure, is known as *ocher*. This form of the mineral resembles some varieties of hematite in general appearance, but it can easily be distinguished from the latter by its streak or powder, which is brownish-yellow instead of red.

The ore as mined consists of nodular masses and small fragments of the more compact varieties mixed with different proportions of ocherous earth, sand and other impurities, such as small particles of rock and small quantities of various minerals.

Commercially, the limonitic ores are grouped as "rock ore" and "wash ore." The former comprises the lumpy portions that may be picked by hand from a natural ore, and which may be shipped without further sorting.

"Wash ore" is the fine, more clayey portion that constitutes the greater part of most deposits. This must be freed from its impurities, which are lighter than the ore, by some form of washing. The most usual method of accomplishing this purpose is to treat the impure ore with a current of water in inclined troughs or revolving cylindrical sieves. The lighter portions are carried off, leaving the heavier limonite behind.

Chemical Composition.—Brown hematite differs from "bog ore" merely in its greater compactness, its greater purity, its texture and its method of formation. Both are composed essentially of the same substance, but the "bog ore" is loose and porous, and contains much clay and organic matter derived from the vegetable material of the marshes in which it occurs.

The composition of pure limonite corresponds to the chemical formula $Fe_4O_8(OH)_6$, which is equivalent to 85.6% of ferric oxide (Fe_2O_3) and 14.4% of water. The metallic content of the pure mineral is 59.89% iron (Fe). The ore, as usually found, however, contains so much impurity that the quantity of iron present rarely exceeds 45%.

The analyses of some of the New Jersey limonites, including several that have been used as ores, are tabulated below, together with a statement of the sources from which the analyses were obtained. In the column of authorities the letters N. J. refer to the Annual Reports of the State Survey. The tenth census report referred to is the report on mining industries (Volume 15, Reports of Tenth Census, Washington, 1886).

Table IX.—Commercial Analyses of Limonite (Brown Hematite) Ores from New Jersey Localities.

Location.	Fe	P	S	Mn	Ti	H_2O	P in 100 Fe	Authority.
Anderson, ...	35.42	.006	4.03	...	tr	....	.02	N. J., 1899, p. 165.
Beatyestown Mine,.	57.41	.107	.010	.29	..	12.04	....	Analyst, R. B. Gage.
Bird Mine, ...	40.50	1.510	.00	.46	..	11.05	3.73	N. J., 1873, p. 119.
Pochuck Mine, ...	38.60	.562	.132	...	..	....	1.456	10th Census, p. 177.
Nolf Farm, ...	39.07	.039	.055	.00	tr	....	.100	N. J., 1879, p. 90.
Rapp Mine, ...	56.71	.050	.019	1.19	..	11.29	....	Analyst, R. B. Gage.
Shield's Mine, ...	42.73	.257	.041	1.40	..	8.88	.601	10th Census, p. 176.
Scott Farm, ...	43.85	.021	.84	...	..	....	.049	N. J., 1879, p. 93.
Shoemaker Mine, ..	51.42	1.048	....	.17	..	....	2.037	N. J., 1899, p. 168.
Slack property, ...	44.33	.170	....	.06	..	....	.383	N. J., 1899, p. 169.
Swayze Mine, ...	47.44	.19	.00	.79	..	....	.400	N. J., 1877, p. 51.
Gulick Mine, ...	49.95	.12	.00	.54	.00	15.95	.25	N. J., 1880, p. 130.
Wean Mine, ...	55.42	.10	.10	...	..	11.80	.180	N. J., 1878, p. 102.

These ores, as will be seen, are low in iron and contain, so far as determined, but traces of titanium. Since, however, titanium was not generally tested for in the Survey laboratory prior to 1879 this generalization possesses little value. It is probable, however, that none of the limonites contain enough titanium to prove detrimental to their use. The ores vary materially in their contents of other components. Their range in sulphur and phosphorus is very wide, some of them with respect to the latter element being well below the Bessemer limit. Manganese is probably present in nearly all cases, as well as numerous other constituents which apparently were not tested for. In one case a complete analysis showed, in addition to the components indicated above, small quantities of calcium, magnesium, nickel, cobalt, potassium, sodium and carbon, both in

the form of carbonic acid and carbonaceous matter. (See Analysis I below.) In one notable instance, that of the ore from the Neighbor Mine, there were found also 3.74% of lead and about 10% of zinc. Analysis II is that of limonite lumps picked from the bog ore of the Gulick Mine, in Middlesex County. Analyses III and IV are of selected samples of pure fibrous ore from the Beatyestown and Rapp mines.

Table X.—Complete Analyses of Limonite Ores from New Jersey.

	I.	*II.*	*III.*	*IV.*
Silica (SiO_2),	19.24	8.90	3.36	4.90
Titanium oxide (TiO_2),	....	.00	......	......
Ferric oxide (Fe_2O_3),	60.99	71.36	82.01	81.15
Ferrous oxide (FeO),	....	......	.00	.00
Alumina (Al_2O_3),	4.72	2.27	.76	.33
Manganous oxide (MnO),	1.81	.70	.38	1.54
Lime (CaO),	.34	tr	.00	.12
Magnesia (MgO),	.70	.15	.01	.04
Pyrite (FeS_2),	.077	.00	......	......
Nickel oxide (NiO),	.06	......	......	......
Cobalt oxide (CoO),	.04	......	......	......
Potassa (K_2O),	1.46	......	.02	.00
Soda (Na_2O),	.10	......	.09	.03
Carbonic acid (CO_2),	.06	......	......	......
Phosphorus pentoxide (P_2O_5),	.588	.27	.246	.114
Sulphur trioxide (SO_3),	....	......	.024	.049
Carbon (in carbonaceous material),	.110	......	......	......
Water below 212°,	.520	15.95	11.86	10.71
Water above 212°,	8.88		1.08	.58
Total,	99.695	99.60	99.84	99.56

I. Washed ore from the Shields mine, Beatyestown. Sample obtained from a pile of 25 tons at Stanhope furnace. Tenth Census, p. 176.

II. Fragments of 40 lumps found in the soil and in the ore beds at the Gulick Mine, East Brunswick township, Middlesex county. Annual Report Geological Survey of New Jersey, 1880, p. 129–130.

III. Selected brown nodules from ore of Shield's mines at Beatyestown, 1907. Analyst, R. B. Gage. The manganese was present partly as MnO_2.

IV. Black dense fibrous nodule from Rapp Mine, near Carpentersville. Analyst, R. B. Gage. The manganese was present partly as MnO_2.

The ore of the Shields mine (I) contained 24.91% of material insoluble in acid and 74.78% of soluble material. The insoluble residue was made up as follows:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
19.24	4.06	tr	.07	.48	1.02	.03	= 24.90

This is the composition of a feldspathic sand.

Besides sand, the ore contains, also, organic matter, pyrite, apatite, and carbonates. Moreover, if all the soluble CaO shown in the analysis is combined with P_2O_5, in the form of apatite, there will remain an excess of .388% of this constituent unaccounted for. This may mean that a portion of the phosphorus is combined with some iron in the form of an iron phosphate. Subtracting all the constituents above enumerated there remains to represent the composition of the limonite the proportion of oxides shown in line A below. Line B gives these same constituents calculated to 100%, and in line C is the analysis of a pure limonite.

	Fe_2O_3	Al_2O_3	MnO	MgO	NiO	CoO	K_2O	Na_2O	CO_2	P_2O_5	H_2O	Total
A	60.90	.66	1.81	.22	.06	.04	.44	.07	.06	.388	8.88	= 73.618
B	82.85	.90	2.46	.29	.08	.05	.59	.10	.08	.53	12.06	= 99.99
C	85.6										14.4	= 100.00

The Gulick ore, being a lump ore—that is, an ore made up of large pieces collected by hand, is necessarily "cobbed" in its collection, and is therefore purer than the Shields ore, which is fine, and therefore mixed with all the impurities deposited with it. It contains only about 10% of insoluble residue, and in it, too, the phosphorus must be in some form other than apatite, since the analysis shows only a trace of lime present.

The samples furnished for analyses III and IV were perhaps as pure specimens of limonite as can be obtained in the State. Both were dense, heavy and finely fibrous and neither showed any evidence of the presence of foreign matter. Here again the figures indicate that the phosphorus is in the form of an iron phosphate. The percentage of lime (CaO) necessary to form apatite with the .246% of P_2O_5 present in sample III is about .30, whereas, in fact the analysis shows none. The only metal

present with which the phosphorus is likely to be combined is iron. The close agreement between the figures of this analysis and the calculated composition of the soluble portion of the Shields ore as shown in line B above is noteworthy.

The two classes of ore—that from the Shields mine and that from the Gulick, the Rapp and the Beatyestown mines—may serve as the types of brown hematite ores most commonly met with. Both are limonites mixed with siliceous and other substances. Both contain manganese and phosphates and neither contains any considerable quantity of sulphur. The lump ore is purer than the wash ore, mainly because the latter is in small pieces which cannot be completely separated from the sand and other foreign substances with which it is mixed. Usually the two are mined together.

A third class of brown hematites which will be referred to more particularly later is characterized by its large content of sulphur. These are now limonites but they have originated in a different way from that in which the more common limonites were produced, i. e., by the decomposition of pyrite, the sulphur in them representing a remnant of the original pyrite which has remained unchanged. This type is probably represented by the ore of the old Pochuck mine.

Metallurgical Value.—The limonites are used chiefly in the blast furnace in mixtures with other ores. Their water content renders them too expensive to be used alone at the present time when anhydrous ores are so abundant. The fuel necessary to be burned in order to drive off their water is more economically employed in smelting more expensive ores. As mixtures, however, they are valuable, especially in connection with the magnetites. When roasted most of the water is driven off and the ore is left as a soft friable mass which binds the harder ores and tends to cause them to smelt more readily than would be the case otherwise. Moreover, the possibility of securing good limonites containing small quantities of phosphorus and comparatively large quantities of manganese increases their value as mixers. Owing to their siliceous character they are particularly useful in mixtures with the rich ores of Lake Superior that contain but little silica. The lean siliceous ores of the lake region are so

expensive by the time they reach New Jersey, on account of the long haulage and the consequent high charge for freight, that they would not be able to compete with the New Jersey ores if these were capable of being furnished regularly and with a constant composition.

MANNER OF OCCURRENCE.

The limonite ores in New Jersey are usually found associated with the blue or Kittatinny limestone, more particularly near its upper and lower contacts. In a few places, however, it occurs under other conditions. At the Edsall mine the ore appears to be in the white (Franklin) limestone, near its contact with gneisses. At the Pochuck mine it appears to be in fault fissures between the white limestone on the one side and the blue limestone and Hardyston quartzite on the other. At the Roseberry and Shoemaker mines it is partly, at least, in the Cambrian slates and quartzites. In all the mines but the Pochuck, however, its origin is apparently similar to that of the ores in the blue limestone. It occurs in very irregularly shaped layers or flat lenses, following the general direction of the contact planes—as steeply inclined vein-like deposits when the contact planes possess dips, and as gently inclined bed-like deposits when the contact planes are more nearly horizontal. The lenses are separated from each other by ferruginous clay or by barren limestone that is very much decomposed. Small masses of compact, rich, fibrous ore are often found imbedded in the clay, but the greater portion of the ore is a mixture of porous, earthy nodules, stalactitic masses, ocherous material and lenses and sharp-edged fragments of jasper or chert. When the ore is in joint fractures there are often intermingled in this mixture sharp-edged fragments of the adjacent rocks, and the whole mass is cemented by compact ore.

The boundaries of the deposits are extremely irregular, the ore often extending into the limestone along its bedding planes, or along joint cracks for considerable distances beyond the main mass of the deposit. (See also pages 43–44.)

DISTRIBUTION.

The greater portion of the limonite, as has been remarked, is in the blue, or Kittatinny, limestone, which in New Jersey occupies the valleys between the Highland ridges and extends from these northward into the Kittatinny Valley, and occurs locally south of the Highlands between the crystallines and the younger Newark beds. The limestone constitutes a portion of the great belt of Cambro-Ordovician beds that stretches from Vermont to Alabama along the Great Appalachian Valley. Everywhere this belt is characterized by the presence of limonite deposits. In the south the deposits are of great magnitude, some of the Alabama mines producing as much as 100,000 tons annually.

To the northeast the belt passes through Cornwall Township, Orange County, New York, where there are a few mines, but it is better developed on the east side of the Hudson River in the southern and eastern portions of Duchess County and in the southeastern portion of Columbia County, whence it passes into Litchfield County, in Connecticut, and Berkshire County, in Massachusetts, and thence northeastward into Vermont. In New York, on the east side of the Hudson River, the mines are of considerable importance.

To the west the north boundary of the limestone belt passes the Delaware River into Pennsylvania just north of Marble Mountain, and its southern boundary crosses the river a short distance south of Musconetcong, which is directly opposite Riegelsville, in Pennsylvania. It passes through Northampton and Lehigh counties into Berks County and thence continues southwesterly via the Cumberland Valley into Maryland. In Pennsylvania the ore deposits in the limestone are numerous. They have been worked extensively in the past and are still yielding abundantly. In 1880 Northumberland County produced 122,000 tons of this type of ore and Lehigh County about 350,000 tons.

In New Jersey the limonite deposits are not as abundant nor are individual deposits as large as they are further south. The ore has, however, been found at a number of different points and

at many of these it has been mined. In succeeding pages the separate deposits so far as they have been exposed are listed and described. (Pp. 51–74.)

ORIGIN.

No careful study of the limonites of New Jersey has been made, but the explanation of the origin of the ore offered for the New York, Virginia and Alabama deposits will probably apply equally well to the New Jersey occurrences.

With respect to the ores in New York, Professor Dana[1] declares that the limonites east of the Hudson River occur in limestone, sericite-slate, clay-slate, mica-schist and quartzite. They are most abundant in the sericite-slate. The ore has resulted principally from the oxidation in place of carbonate of iron and ferriferous limestone, and to some extent, also, of the iron-bearing minerals of the associated schists. The slates near the ores have been changed to soft clay, largely through the oxidation of ferrous carbonate. Iron silicates, like biotite, chlorite, etc., would also yield to oxygen and moisture, and give up their iron, and pyrite, if it existed, would be likewise decomposed and dissolved, thus adding more iron to the accumulating store. But the nearly total absence from the ore of sulphur (seldom over one-tenth per cent.) appears to be evidence that pyrite played a very subordinate part in the production of the limonite. The character of the beds indicates that their formation required only the access of air and moisture to the minerals furnishing the iron, though surface drainage may have played an important part in their accumulation, for the largest mines are situated off the mouths of valleys or near slopes that directed the rain water southward.

Lewis[2] later showed that some of the ore contains much more than .10% S., but, nevertheless, they are comparatively low in this element, and the views of Dana are essentially upheld.

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[1] Geology of Vermont and Berkshire. Amer. Jour. Sci. III. xiv. (1887) p. 132.

[2] Trans. Amer. Min. Eng. V. 1877, p. 235.

Hobbs,[1] on the contrary, thinks the source of the iron for the New York limonites is almost exclusively the pyrite of the neighboring schists. He finds the Columbia and Dutchess County limonites, and those of Litchfield County in Connecticut and Berkshire County in Massachusetts to occur near the contact of the Stockbridge (Cambro-Ordovician) dolomite and the overlying Hudson schist. They are frequently so closely associated with faults as to lead to the conclusion that faulting has determined the positions of the deposits. The iron is supposed to have been obtained by the solution of pyrite in the neighboring schists, which form highlands in the vicinity of the mines. The solutions thus formed were directed in their circulation by the faults. They flowed through portions of the Hudson schist faulted down between dolomite walls and replaced this, producing sheet-like deposits of limonite lying upon the dolomite. The principal difference between this theory and that of Dana is that in Hobbs' theory the iron is supposed to have been brought into its present position by solutions originating elsewhere, while according to Dana the source of the metal is mainly within the rock in which the ores now occur.

In the South the limonites are much better developed than in New England, New York and New Jersey, and a much better opportunity is thus afforded for studying them. Here they have been shown to be largely residual deposits, produced by the solution of limestone and its removal by water. The iron carbonate which was originally in the limestone, or which was brought to it by the percolating waters, is oxidized by contact with the alkaline waters resulting from the solution of the limestone and is precipitated in the hydrated form (see p. 35) just as hydrates of the metal are precipitated in the laboratory by the addition of an excess of alkaline carbonates to solutions of its salts.

Whatever its original source the precipitated oxide first accumulates in any cracks in the rocks through which water may pass, forming masses of comparatively pure and compact limonite. When the cracks are in limestone this rock is gradually dissolved and its place is taken by newly precipitated limonite. By gradual replacement of the rock the deposit grows until finally it may

[1] Economic Geology, Vol. 2. No. 2, 1907, p. 153–181.

become sufficiently large to warrant working. The undissolved impurities in the limestone remain behind and become mixed with the limonite, the whole forming a typical ore deposit. The method of formation explains the tendency of the deposit to seek contacts between limestone and slates on the one hand and those between the same rock and gneisses on the other, since it is well known that such contacts between different rock layers offer favorable conditions for the percolation of ground waters. The circulating waters carry the ore material into their channels, where it is precipitated by the alkaline solutions originating in the limestone.

The source of the ore in New Jersey is probably almost exclusively the limestone. The gneisses of the Highlands are in the main quite fresh. Their ferruginous components have suffered little alteration and therefore have not yielded a great quantity of iron to the solutions that deposited the limonite. Moreover, they contain but an extremely small quantity of pyrite[1] or its alteration products. Further, the magnetite in the ore lenses is likewise fresh and unaltered. It shows little evidence of having suffered partial solution. With these three sources of iron eliminated there remains only the limestone to be considered. This always contains a small percentage of iron, which, in some cases, may reach 1.25% of Fe_2O_3, and in one case, that of the Beatyestown mine (see p. 70), there is known to be present as high as 82.23% of $FeCO_3$. The composition of some specimens of the limestone is shown in the accompanying table. When comparing the composition of the limestone with that of the limonites it must be remembered that the latter represent the accumulation of the undissolved residue of great masses of the former, and therefore that it is not necessary for the original rock to be very rich in iron to furnish abundant material for the production of ore deposits of great size.

[1] In the report for 1868 it is stated that all the ore originated "from sulphides of iron in the adjacent gneissic rocks, which, by atmospheric agencies, have been converted into soluble sulphates, and these latter, when in solution, have, by chemical reaction on the magnesian limestones, produced precipitates of peroxide of iron, and solutions of sulphates of lime and magnesia." (Cook, G. H., Geology of N. J., 1868, p. 663.)

It is probable that there has been some addition made to the ore deposits by waters draining from the Highlands and carrying down with them salts of iron, but that the greater portion of the limonites met with in the limestone has originated in some other way seems more plausible.

Table X.—Analyses of Cambro-Ordovician (Blue) Limestone of New Jersey.

	CaO	MgO	Fe_2O_3		Al_2O_3	K_2O		Na_2O	SiO_2	H_2O	CO_2	P_2O_5	Total.	
Hilliard's Quarry, Peapack, ...	26.3	17.4	1.3		4.0	0.3		0.3	8.0	0.7	41.1		99.4	N. J. 1868, p. 393
Craig's Quarry, Peapack, ...	30.3	18.3		1.6					4.1		44.1		98.4	N. J. 1868, p. 393
Craig's Quarry, Peapack, ...	31.6	18.3		3.0					1.6		45.2		99.7	N. J. 1868, p. 393
Shimer's Quarry, Springtown, ...	29.2	18.1	0.6		1.8		0.8		3.6	0.6	43.6	0.2	99.2	N. J. 1868, p. 394
Kennedy's Quarry, Springtown, ...	30.1	20.1	0.6		0.2		0.2		3.5	0.4	44.4	0.2	99.7	N. J. 1868, p. 394
Warren Quarry, Phillipsburg, ...	30.8	19.2		1.1					3.6		45.4		100.1	N. J. 1868, p. 394
Sparta, Sussex Co., ...	28.5	17.3		1.7					9.9	0.3	41.5	tr	99.2	N. J. 1868, p. 394
Chandler's Island, Vernon, Sussex Co.,..	27.6	17.9	0.6		1.1		0.5		9.9	0.2	41.9	0.2	99.9	N. J. 1868, p. 395
Wantage, Sussex Co., ...	27.9	17.7	0.6		0.3		0.3		11.2	0.3	41.4		99.7	N. J. 1868, p. 395
Oxford Furnace, ...	50.30*	42.40*	0.33		0.97				5.5			0.18	99.68	N. J. 1876, p 56

* As $CaCO_3$ and $MgCO_3$

The limestones contain all the materials found in the ores except those occurring in very small quantities and even these might have been discovered if the analyses had been made with that purpose in view.

In a few special cases the brown hematites have apparently had a different origin. This is true particularly of the ore at the Pochuck mine where the deposits fill fault fissures which lie between the white Franklin limestone and gneiss on the one side and the blue Cambrian limestone and quartzite on the other. The condition of the mine does not afford opportunity for a careful survey, as it has been abandoned for many years. Dr. Spencer, who has examined carefully the ore deposits in the neighborhood of Franklin Furnace thinks that the Pochuck occurrence is an example of a deposit resulting from the decomposition of pyrite. He believes it represents a vein of pyrite that once filled a broken fault zone and which, by its oxidation, yielded the present ore, just as ferruginous sulphide veins everywhere are altered near the surface to limonitic compounds. If this is a true view of the origin of the Pochuck deposit the ore should pass into sulphide at about the level of the ground water, below which oxidation would be arrested.

While this is an unusual mode of origin for New Jersey limonites it is a well-established method for certain ores in Pennsylvania and Virginia. In the latter state, in Floyd, Grayson and Carroll counties, there is a narrow belt of limonite 20 miles wide that has been worked extensively in recent years. At the surface the ore contains from 40 per cent. to 41 per cent. Fe, but below the water line it passes uniformly into pyrite or pyrrhotite.

In Franklin County, Pennsylvania, important deposits have been found in the Hudson River slates where the ore has likewise been thought to have resulted from the alteration of pyrite,[1] "the large percentage of sulphuric acid which they invariably contain going to confirm this view." An analysis of a sample of 129 pieces of ore taken from Stouffer's ore-bank, east of Mercersburg, gave:

Fe	*Mn*	*S*	*P*	*SiO_2*	*P in 100 pts. Fe.*	*Authority.*
40.850	tr	.297	.037	20.030	.090	10th Census, p. 198

[1] McCreath: Second Pennsylvania Survey, Rep. M3 p. x.

This type of ore differs from the more usual types of limonite in its small percentage of manganese and phosphorus and its large content of sulphur.

A complete analysis of the Pochuck ore is not available, but a partial analysis made for the Tenth Census Report gave the following figures:

Fe	*S*	*P*	*P in 100 pts. Fe.*	*Authority.*
38.6	.132	.562	1.456	10th Census, p. 177

This shows the presence of less sulphur than in the Mercersburg ore, and much more phosphorus. It furnishes no basis for argument either in opposition to, or in favor of, the view that the ore is derived from pyrite.

Very recently H. M. Chance[1] proposed to ascribe all of the limonites in the post-Cambrian limestones throughout the eastern United States to the oxidation of pyrite in place. His explanation of the origin of the limonites differs from the explanations previously proposed in which pyrite is regarded as the source of the iron, in that the sulphide is supposed to have been deposited with the sediments forming the rocks in which the ores are now found. This being oxidized in place resulted in accumulations of limonite which settled down as the general surface of the country was lowered by erosion and thus formed masses of great size. In the previous theories the pyrite is regarded as having been introduced as veins after the rocks were consolidated.

PRODUCTION.

Although more or less limonite has been raised from the New Jersey ores for more than 40 years there are no statistics that indicate the quantity obtained annually or the gross aggregate for the period. In 1871 and 1872 the production was estimated at 15,000 tons. In 1880 the total yield of all the mines was 15,503 tons, of which 12,354 tons were from those in the neighborhood of Beatyestown. Between 1872 and 1880 the Shields mine alone produced 41,121 tons. After 1880 the yield of "brown

[1] Bi-Monthly Bull. Amer. Inst. Min. Eng. Sept., 1908, p. 791–808.

hematite" rapidly diminished until in 1885 only an inconsiderable quantity was being raised from two small mines. There is no record of any of this class of ore being produced in the state between the years 1893 and 1906. In the latter year one of the Beatyestown mines was reopened and a small quantity of ore was obtained, and in 1907 and 1908 additional small quantities were raised from the Shoemaker and Roseberry mines. The Shoemaker mine is still operating.

In the table below the life of each of the limonite mines is indicated in so far as it can be determined from the published records. The years during which the several mines were worked are indicated by the sign +. It does not necessarily follow, however, that the mines were inactive in all the years that are not so indicated, since the records are very fragmentary. For instance, there is no record for the year 1869, or for many of the years since 1880. The table is of value only so far as its information is positive. That is, it indicates only that in certain years and during certain periods of years certain mines were producing ore. A glance at it teaches that while most of the mines have been worked in a desultory manner some of them have yielded steadily, being closed down only when the price of ore fell to figures too low to enable them to operate profitably.

Table XI.—List of Limonite Mines in New Jersey and the Record of Their Periods of Activity.

	Before 1840.	Bet. 1840–1856.	Bet. 1856–1868.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1885.	1889.	1890.	1891–1905.	1906.	1907.	1908.
Anderson,	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Bird,	..	..	..	..	..	..	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Broadway,	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Brown,	..	..	..	..	..	..	..	..	+	+	..	..	..	..	..	+	..	..	..	..	..	..	..
Carpenter,	..	..	+	+	..	+	+	+	+	..	..	..	..	..	..	..	+	..	..	..	..	..	..
Cline or New Village,	..	+	..	..	..	..	..	+	+	..	..	..	..	..	..	+	+	..	..	..	..	..	..
Dafford,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	+	..	..	..	..	..	..	..
Edsall,	+	+	..	..	..	+	+	+	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fitz,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	+	..	..	..	+
Henry Hamlen,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	..	..	..	..	..	..	..
Wm. Hamlen,	..	..	+	+	+	..	..	..	..	..	..	+	..	..	+	+	..	..	..	..	..	..	..
Neighbor,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	..	..	..	..	..	..	..
New Village, see Cline,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pochuck,	+	+	+	+	..	+	+	+	+	+	+	+	..	..	..	..	..	..	..	..	..	..	..
Radley,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	+	..	..	..	..	..	..	..
Rapp,	..	..	..	+	..	..	..	..	..	..	..	..	..	..	+	+	+	..	..	..	..	..	..
Riegel,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Roseberry,	..	..	..	..	..	..	..	..	..	..	+	..	..	..	..	+	..	..	+	..	+	..	..
Shields,	..	..	..	+	+	+	+	+	+	+	+	+	+	+	+	+	..	..	..	..	..	..	+
Shoemaker,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	+	+	..	+	+
Stewartsville, see Thatcher,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Swayze Hematite,	..	..	..	..	..	..	..	..	..	..	..	..	+	..	+	+	..	..	..	..	..	..	..
Thatcher or Stewartsville,	..	..	..	..	..	..	..	..	+	+	..	..	..	..	..	..	..	..	..	..	..	..	..
Thomas,	..	..	..	..	..	..	..	..	..	..	..	+	..	..	..	+	..	..	..	..	..	..	..
Wean or Wene,	..	..	..	..	..	..	..	..	..	..	..	..	+	+	+	+	..	..	..	..	..	..	..

EXPLORATION.

In searching for limonites the explorer is deprived of those great aids—the dip needle and magnetic compass—which enable him so successfully to follow leads of magnetite. Since limonite is not magnetic it cannot of course affect the compass. The searcher for limonite must therefore rely entirely upon surface signs and follow these by test-pitting.

The existence of the ore beneath the surface is recognized by the presence of a brown or yellowish orcherous soil containing little fragments of ore, with the appearance of which the explorer must have made himself familiar. Sometimes the upper soil may have lost its orcherous color by leaching, but when this is true small fragments of ore may still occur in it. If ore is suspected under a light colored soil recourse must be had to the dirt thrown out from the bottom of wells or other excavations. If this is also light colored the chances of finding ore in the immediate vicinity are poor. If the surface indications seem favorable to the existence of ore beneath, and the dirt from the bottom of excavations also affords favorable indications, the neighborhood should be tested with pits reaching to rock, or if ore is penetrated, with pits of sufficient depth to test its availability as a workable deposit. The pits should be so placed as to determine the breadth and length of the area and should of course not be arranged in a line. If the boulder or drift layers on the surface are not too deep the large rocks may be removed by hand and the soil tested by boring with an auger. This method, when practicable, is preferable to test-pitting, as it does not disturb so much of the soil or any crop growing upon it. When the surface layer is clay, boring is very much more efficacious than test-pitting, besides being much cheaper.

In making search for the ore it should be remembered that its most favorable situations are near contacts of the Kittatinny limestone with other rocks. It should also be borne in mind that as the ore is mainly of residual origin it can only be present in quantity where the limestone has been decomposed. It is useless therefore to expect to find large bodies of ore in places where fresh limestone layers outcrop.

RESERVE.

That there is still a considerable quantity of good limonite in the valleys between the Highland ridges is beyond question. Many of the mines formerly worked were abandoned not because of the exhaustion of the deposits, but because the low prices at which ore was selling a score of years ago made the venture of

mining it unprofitable. The discovery of huge accumulations of excellent hematite in the Mesabè district and the exploitation of the Alabama ores has had a depressing effect upon the limonite industry in New Jersey. Iron can be manufactured from the Lake Superior and Alabama ores at a cost which prevents competition by Eastern furnaces using local ores except in cases where abundant supplies can be obtained cheaply. Fortunately, in this State, the magnetites can be produced at a profit at prices which enable them to be utilized extensively in New Jersey furnaces. With an increase in the value of iron that bids fair to be permanent, the limonites will again be in demand, but this time will not arrive perhaps until the supply of Mesabè ores that can be mined with steam shovels becomes less abundant. When it does arrive, however, New Jersey limonites will again be produced, probably not in very large quantities, but in sufficient quantity to be worthy of consideration in any discussion dealing with the value of the State's resources.

LOCALITIES.

Limonitic ores have been reported to exist in Warren, Sussex, Morris, Hunterdon, Middlesex and Passaic counties. In many of these localities the deposits have been large enough to warrant working when the market price was satisfactory. Where the deposits have been opened up and shipments made from them we have the mines, the names which are enumerated on page 49. Openings from which no ore has actually been shipped are known as explorations. A list of all the occurrences reported is given below.

Table XII.—List of Known Limonite Localities in New Jersey.

HUNTERDON COUNTY.

Bethlehem Township, 1½ miles S. W. of Asbury on road between Asbury and Bloomsburg. Hazard Exploration.

Bethlehem Township, 2 miles S. W. of Asbury. Wolverton Farm Exploration.

Bethlehem Township, 1 mile E. of Bethlehem. Wean Mine.

Holland Township, 1½ miles N. of Amsterdam. Snyder Farm Exploration.

Holland Township, near Little York. Exploration.
Holland Township, near Delaware River. Nolf Farm Exploration.
Lebanon Township, Radley Mine.
Lebanon Township, 2 miles N. E. of Califon. Dafford Mine.
Lebanon Township, 2 miles N. E. Califon. Neighbor's Mine.
Union Township, ½ mile W. of Clinton. Bird Mine.

MIDDLESEX COUNTY.

East Brunswick Township, between Milltown and Dunham's Corners. Gulick Exploration.

PASSAIC COUNTY.

New Milford Township, near Greenwood Lake. Cooley's Exploration.

SUSSEX COUNTY.

Hardyston Township, W. foot of Pochuck Mt. 2 miles N. of Hamburg. Scott Farm Exploration.
Hardyston Township, 2 miles N. E. of Hardistonville. Edsall Mine.
Sparta Township, 2 miles S. W. of Ogdensburg. Van Kirk Exploration.
Sparta Township, 1 mile N. E. of Pinkneyville.
Vernon Township, ¼ mile N. of McAfee. Pochuck Mine.

WARREN COUNTY.

Franklin Township, near New Village. Cline or New Village Mine.
Franklin Township, ½ mile S. of Broadway. Broadway Exploration.
Franklin Township, ½ mile W. of West Portal. Slack Exploration.
Franklin Township, ½ mile N. of Stewartsville. Thatcher Mine.
Greenwich Township, 1 mile S. of Carpenterville. Carpenter Mine.
Greenwich Township, 1 mile S. of Carpenterville. Rapp Mine.
Greenwich Township, 1 mile S. of Carpenterville. Riegel Mine.
Greenwich Township, north foot of Silver Hill. Exploration.
Harmony Township, at Upper Harmony. Exploration.
Harmony Township, road between Upper and Lower Harmony. Ramsay's Farm Explorations.
Hope Township, near Shiloh. Shiloh Mine.
Hope Township, 3 miles S. of Blairstown. Swayze's Hematite Mine.
Hope Township, near Smith's Mill, north of Green Pond. Exploration.
Lopatcong Township, 2 miles E. of Phillipsburg. Hamlen Mine.
Mansfield Township, ½ mile N. of Beatyestown. Brown Mine.
Mansfield Township, ½ mile N. of Beatyestown. Shield Mine.
Mansfield Township, ½ mile N. of Beatyestown. Thomas Mine.
Oxford Township, 2 miles S. of Oxford Church. Roseberry Mine.
Oxford Township, 2¼ miles S. of Oxford Church. Shoemaker Mine.
Oxford Township, 2¼ miles S. of Oxford Church. Fitzz Mine.
Oxford Township, near Bridgeville. Titman Exploration.
Pahaquarry Township, near the Water Gap. Exploration.
Washington Township, near Anderson, on road to Port Colden. Anderson Mine.

DESCRIPTION OF INDIVIDUAL MINES.

The limonite mines of New Jersey and the principal explorations are situated in the valleys lying between the gneiss ridges of the Highlands. Most of them are on the sides of the valley tracts and near the contacts of the Kittatinny limestone and the gneiss. Others are near the centers of the valleys near contacts of the limestone and the overlying Martinsburg slates. A few seem to be at some distance from visible contacts of either kind, but in these cases the mine developments have usually revealed rocks other than limestone very near the ore deposits. In the descriptions below, the mines are discussed in order, beginning with those in the valley farthest northwest and proceeding northeastward along the valley troughs. Thus all the mines in a given valley are described before those of the next one to the south are taken up. The figures prefixed to the names of the mines refer to the map, on which the location of the mines are indicated by the same numbers.

MINES IN THE KITTATINNY VALLEY.

The Kittatinny valley lies between the Kittatinny or Blue Mountain on the northwest and the Highlands on the southeast. Several explorations for limonite have been made in the limestone and slate in which the valley is carved, but only one, or possibly two, have ever proven of economic importance.

The openings in this valley are the Shoemaker, Fittz, Roseberry, Shiloh and Swayze's Hematite mines and the Scott Farm exploration. The Swayze mine is in a slate area, but it is probable that the slates at this place were thinly covered by an overthrust mass of limestone now removed by erosion. The mine produced a small quantity of ore in the decade between 1870 and 1880. The other four mines are on the flanks of gneiss ridges where the gneiss is in contact with the Kittatinny limestone. Of these the Shoemaker mine is by far the most important.

(1) *The Shoemaker and* (2) *Fitts Mines.*

Along the west side of Scott's Mountain, in Oxford Township, Warren County, where the crystalline rocks are in contact with the Kittatinny limestone, are several shafts and tunnels that were formerly actively worked, yielding limonite of a slightly different character from that found elsewhere in the limestone valleys (Fig. 2). Very little can be learned from the openings at present, as only small portions of their dump-heaps remain.

The southernmost of the openings comprised the Shoemaker mine, the shafts of which are at the base of the mountain on Buckhorn Creek, two miles south of Belvidere. The mine was discovered in 1888 and worked for several years thereafter, yielding several thousand tons of ore. It was then closed and remained idle until 1906, when it was again explored, without, however, producing much ore. Later it was worked more energetically and at the present time (January, 1909) it is producing about 900 tons per month.

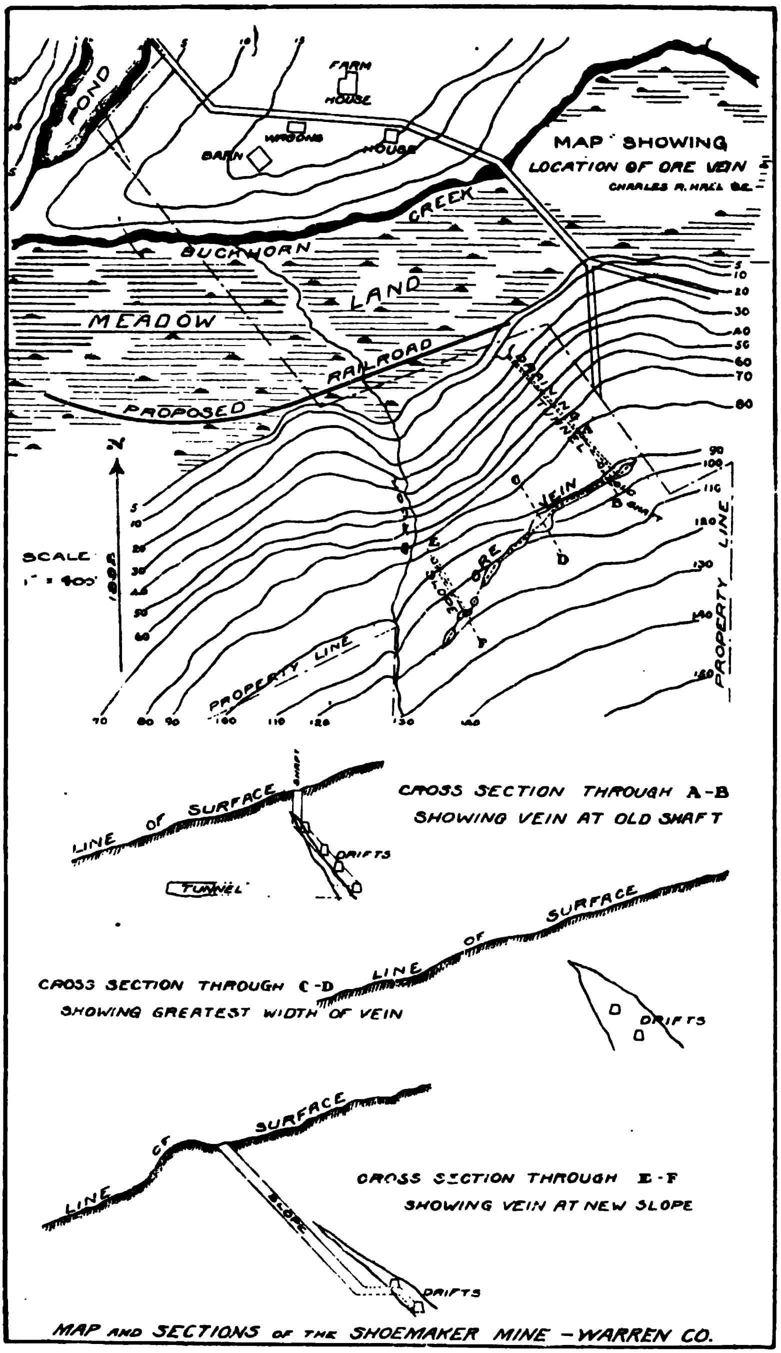
The mine is entered by two shafts and a tunnel, the latter having been constructed for drainage purposes. The original shaft, which was to the northeast, was put down on the foot wall of the ore, vertically for 20 feet and then at an angle of about 50° southeast for 60 feet. It was not steep enough, however, and consequently passed through the ore deposit. A second slope was then begun 400 feet southwest of the old shaft. This was sunk to a depth of 230 feet and terminated in a drift of 606 feet driven along the length of the ore-body. The width of the ore-body varies between 2 and 40 feet, increasing as it descends. Its top is extremely irregular[1].

The ore is a fairly rich limonite, containing however a very high percentage of phosphorus. The average analysis of a shipment of 125 carloads received by the Thomas Iron Company in 1893 gave 46.73% of iron.

The partial analysis of another shipment yielded:

Fe	*P*	*Mn*	Al_2O_3	*CaO*	*MgO*	SiO_2	*P in 100 pts Fe.*	*Authority*
51.420	1.048	0.17	3.86	1.68	0.18	8.85	2.037	N. J. 1899 p. 168

[1]Engineer's Report to Shoemaker Mining and Manufacturing Co.



MAP AND SECTIONS OF THE SHOEMAKER MINE — WARREN CO.

Fig. 2.

(After C. R. Hall. Courtesy of the Shoemaker Mining and Manufacturing Company.)

The ore raised in 1906 analyzed as follows:

Fe	*P*	*S*	Al_2O_3	*CaO*	*MgO*	SiO_2	*Water*	*Authority* Laboratory
48.20	0.267	tr	2.09	0.99	0.72	10.38	Not Det.	Secaucus Furnace

In general the ore is so soft that little powder is used in the mine except when an occasional lump is encountered too large to be removed *en masse*. It is mixed with clay, sand and slate to such an extent that much of it requires washing before shipment.

The manner of occurrence of the ore is not definitely known, though a tunnel driven into the mountain from the valley for the purpose of drainage gave a good section 350 feet in length. This tunnel penetrated 35 feet of dark green talcose slate, 300 feet of a light buff-colored clay slate, 3 to 12 feet of flint or chert, and ended in ore from 4 to 12 feet thick. On the hanging wall side of the ore, which dipped southeast at about 50°, was a body of very white clay. This may represent a bed of feldspathic Hardyston quartzite lying between the ore and the fresh gneiss of the mountain. The flint referred to as lying under, the ore is probably a remnant of the Kittatinny limestone which has escaped decomposition. It was probably originally a chert bed in the limestone. The dump at the shaft contains many pieces of ore composed of sharp-edged fragments of a yellowish slate cemented together by limonite, thus forming a well-defined breccia such as sometimes occurs between the mountain gneisses and the valley sediments. The slate which lies between the chert and the blue limestone is apparently a slaty phase of the limestone near the base of the series.

The ore probably lies partly at least, in a fault zone in the Cambrian, into which it was carried by downwardly percolating waters which found their easiest courses in the fault rubble lying against the underlying crystalline rocks. In this was deposited the limonite which partially replaced the slate and partly cemented the fragments into a breccia.

It is reported that another "vein" exists 250 feet east of that worked at the mine. It is said to be parallel to the Shoemaker vein and to be the extension of that formerly worked at the Rose-

berry mine. No evidence of this vein, however, can be detected on the surface.

References: N. J. 1890, p. 52; 1891, p. 235; 1899, p. 168.

The Fitz (or Fritts) mine adjoined the Shoemaker on the northeast. It was worked to some extent in 1889 and 1890, as an independent mine, but is now part of the Shoemaker property.

Reference: N. J. 1890, p. 53.

(3) *The Roseberry Mine.*

The Roseberry mine was a mile northeast of the Fitz mine, well upon the hill forming the east slope of the valley of Buckhorn Creek, a narrow depression lying between two gneiss ridges, and extending northward from the Fitz mine toward Oxford Church. Another mine of the same name was situated farther south, on the west side of the ridge separating the valley referred to from that of the Delaware River. The latter, however, produced magnetite. The ground around the limonite mine was tested by a dozen shafts and pits in 1879 or 1880 and about 500 tons of ore were raised. It was again worked during the first half of 1906. An old shaft was opened and retimbered and some wash ore was raised. Preparations were made for reopening it again in 1908, but at the present time mining has not been resumed.

The ore in this mine was found at depths of from eight to sixty feet in a series of pockets that are arranged in a line trending northeast. The pockets are apparently in a slate that has the geological position of the Hardyston quartzite. When followed downward the separate deposits merged and formed a layer dipping 45° southeast. At the depth of 80 feet, however, the dip changes suddenly to the northwest. At this point the ore layer impinges against the mountain gneiss which lies to the east and is deflected northwest along the contact plane between the gneiss and ore-bearing rock. Where the deflection occurs the ore-body is much thicker than elsewhere. It is probable that the ore bed is the same as that worked at the Shoemaker mine. The ore, however, is softer and less pure and all of it has to be washed be-

fore shipment. If the ore body is continous between this mine and the Shoemaker the quantity of ore available is very large, possibly several millions of tons.

References: N. J. 1880, p. 129; 1890, p. 53.

(4) *The Shiloh Mine.*

The Shiloh Mine was near Shiloh, in Hope Township, Warren County. It developed only a small quantity of ore in test pits that were dug at the west foot of Jenny Jump Mountain near the contact of the gneiss and limestone, during 1873. The mine never yielded any ore.

Reference: N. J. 1873, p. 89.

(5) *Swayze's Hematite Mine.*

Swayze's Hematite, or the Osman Mine, lies 3½ miles south of Blairstown, Hope Township, Warren County, northeast of Silver Lake. East of the mine are slate outcrops and west of it exposures of limestone. About three-fourths of a mile to the northeast is a second opening known as the Shuster Mine. Its ore probably was of the same character as that of the Swayze Mine, but there is no record of its ever having been worked. The pits at the Swayze mine pass through an unassorted drift consisting of blue clayey earth and gravel, cobbles and boulders. Under the drift is yellow ochery clay that is supposed to be a decomposed blue slate (Martinsburg slate). In the shaft the ore-bed was eight feet thick, but drifts cut to the east and west indicate much variation in the thickness. The ore appears to occur over an area of several acres in workable quantity.

Ore was first discovered at this place during 1872 or 1873, but the mine was first opened in 1877, and 100 tons of ore were produced. There is no record of the amount raised in succeeding years until 1880, when 550 tons were mined.

Most of the ore was wash ore, but with this were some bomb-like masses and small fragments. An analysis of an average sample obtained from a pile at the shaft gave:

Fe	Mn	P	S	Ins.	H_2O	P. in 100 pts. Fe.	Authority
47.44	.79	.19	.00	12.40	13.20	.400	N. J., 1877, p. 51

References: N. J., 1877, p. 51; 1880, p. 121; 10th Census, p. 177.

(6) *Scott Farm Exploration.*

At the west foot of Pochuck Mountain, 2 miles north of Hamburg, in Hardyston Township, Sussex County, a small deposit of limonite was opened in 1879. A sample obtained from the owner analyzed:

Fe	S	P	Authority
43.85	.84	.021	N. J., 1879, p. 93.

Reference: N. J., 1879, p. 93.

MINES IN THE SPARTA VALLEY.

The Sparta Valley begins at Sparta, extends north and northeast for 18 miles to the State line between New Milford, New York, and Glenwood, New Jersey, where it opens into the wider Kittatinny Valley in which lie Amity and Edenville, New York. The only two producing limonite mines in this valley are the Pochuck and Edsall, the former near McAfee and the latter near Rudeville. Both have been important sources of ore, but neither is now active. They are among the oldest mines in the Highlands. Besides these there are also within the limits of the valley several hematite mines, that will be referrd to in another place, a number of magnetite mines and the famous zinc mines at Franklin Furnace and Sterling Hill.

(7) *The Edsall Mine.*

The Edsall Mine is 2 miles northeast of Hardystonville, in Hardyston Township, Sussex County. It is situated in a slight depression between the base of Hamburg Mountain and a small knob of pegmatite to the west. The depression is probably underlain by Franklin limestone, although it has been stated that the ore is in a ferruginous gneiss.

The mine is one of the oldest limonite mines in the State. It was worked extensively prior to 1840, since in this year the ore is reported to have been removed from an excavation 140 feet long and 40 feet deep. For some years before 1869 the mine

had been idle, but it was opened again in 1870 and worked until 1873, when it was finally abandoned. During its life it is reported to have yielded a large quantity of ore of the same general character as that of the Pochuck Mine. The situation of the mine near the contact between the white limestone and the gneiss of Pochuck Mountain is exceptional for deposits of this character in New Jersey.

References: N. J., 1840, p. 91-92; 1855, p. 164; 1868, p. 663; 1869, p. 54; 1871, p. 32; 1872, p. 20; Folio No. 161, U. S. Geol. S., 1908, p. 24; Geologic Atlas of N. J., No. 2, 1908, p. 24.

(8) *The Pochuck Mine.*

The Pochuck Mine is on Pochuck Mountain about a mile west of McAfee, in Vernon Township, Sussex County, on the west slope of a prominent ridge of Franklin limestone. (See Fig. 3.) The mine was first worked as an open cut about 1835. As

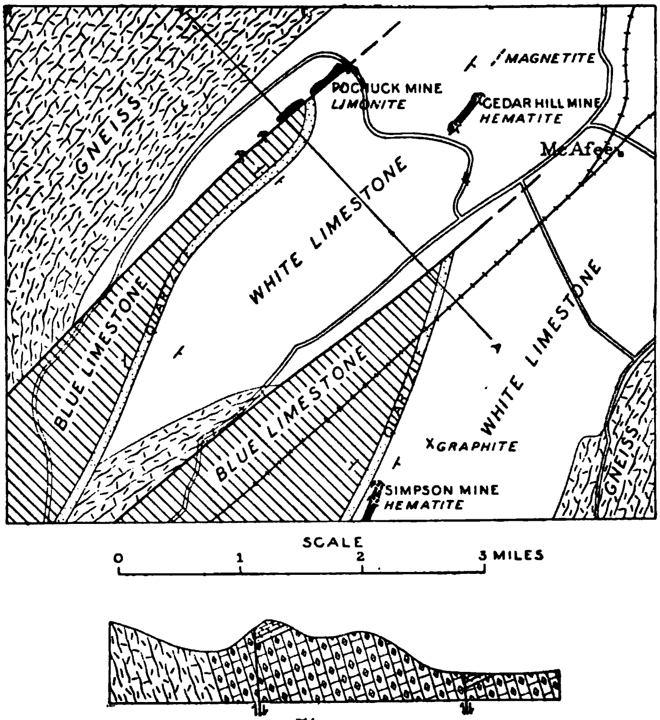


Fig. 3.

Geologic Map and Section, vicinity of the Pochuck Mine. (After A. C. Spencer.)

early as 1854 the ore had already been removed from an excavation 600 feet long and from 60 to 80 feet deep. The mine was idle in this year and had not been worked for several years previously. In 1868 it was again active and with the exception of a few short periods it continued in operation until its abandonment in 1876. The mine has been a large and important producer.

The ore is a brown hematite occurring in stalactitic, mammillary and botryoidal masses mixed with clay and sand with which are associated "large masses of quartzose rock of a honeycomb or cellular structure, containing fibrous limonite of a very poor quality."[1] There is also present in the ore a decomposed feldspar and other constituents of the adjacent gneisses.

The composition of the ore determined by the analysis of a sample taken from 75 tons at the Franklin Furnace is

Fe	*P*	*S*	*P in 100 pts Fe*	*Authority*
38.6	.562	.132	1.456	10th Census, p. 177

The ore also contains graphite. It will be noticed by reference to the figures that it contains much more phosphorus than is usual in the limonites and a considerably larger proportion of sulphur. In spite of this fact it is reported by Rogers to have been much sought by the furnaces of the early part of the 19th century. He declares that

> "The mineral is of excellent quality, yielding a much superior iron to that procured from the magnetic ores of the adjacent primary districts. The facility with which it may be smelted in blast furnaces, compared with the magnetic ore, is another great recommendation. * * * Though but five or six years in use, this ore has already become rather extensively worked, being not only smelted at a large furnace recently erected near Hamburg, but hauled over the Wallkill Mountain a distance of 12 miles to Clinton Furnace, and a still greater distance to Ryerson's Furnace, near Pompton."[2]

The deposit is between white limestone (Franklin limestone) on the one side and blue limestone (Kittatinny limestone) and slates (Hardyston quartzite) on the other. The white limestone is intruded by an acid crystalline rock (the Byram gneiss), the

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[1]N. J. 1868, p. 663.

[2]H. D. Rogers: Final Report, Geol. of New Jersey, Phila., 1840, p. 91.

decomposed remains of which formed the walls of the ore to a depth of 100 feet and for a distance of 600 feet in length. The workable ore occurs more particularly, so far as can now be seen, in a fault fissure at the contact of the white limestone with the blue limestone and its basal layer of Hardyston quartzite.

"On the downthrown side of the displacement a tongue of blue limestone coming in from the southwest extends past some of the old pits, but decreases in width and terminates a short distance south of the main workings. This well-bedded and unmetamorphosed limestone contains strata of limy shale, and is underlain by a thin irregular bed of [Hardyston] quartzite. The latter rests upon the coarsely crystalline white limestone which forms the main country rock of the ridge between the mines and the valley at McAfee. The dip of the blue limestone strata is toward the northwest, or in the direction of the fault. At the mines and to the north no rock outcrops appear west of the fault until the slopes of Pochuck Mountain are reached. To the south, however, white limestone outcrops at various points on the westward slope of the hill, and the position of the fault is clearly shown by several prospecting pits extending in a nearly straight line for about 1200 feet southwest of the principal mine opening. Still farther south the fault can be accurately located by outcrops of white and blue limestone no more than 3 feet apart. At the place where the position of the fault is so closely determined no iron ore exists.

"The mine openings show that the main body of ore occurred beyond the north end of the blue limestone tongue inclosed in the older crystalline rocks. These rocks comprise white limestone as the principal rock; dikes of pegmatite, evidently intrusive; and layers of light-colored granitoid gneiss, which are perhaps also intrusive into the limestone. * * * The layers of gneiss included in the white limestone strike northeast and southwest and stand approximately vertical or are steeply inclined to the southeast. One of them, which has been exposed by the caving of the mine, is perhaps 10 feet in width, and others outcropping a fourth of a mile to the northeast are somewhat wider. * * *

"The more southerly pits have exposed a bed of reddish-brown shale, which lies east of the fault and evidently forms the east wall of the ore. This shale presumably corresponds with the shale strata mentioned above as being interbedded with the blue limestone. Its appearance, however, is quite different from that of the shale exposed on the east side of the fault farther south, for near the mines it shows little evidence of stratification and is impregnated with iron oxide and in places contains minute but abundant scales of graphite. In the same pits are found large masses of sintery quartz rock showing honeycomb or cellular structure. This rock contains flakes of mica and of graphite, and through it here and there are irregular masses of limonite. Limonite also occurs in minute crystals which have the form of pyrite and are evidently derived from the decomposition of that mineral. The presence of this sintery quartz-carrying limonite that can be so definitely proved to be derived from pyrite suggests that the iron ore as a whole

may have been originally a deposit of pyrite formed by mineral-bearing waters from a deep-seated source rising along the fault which has been shown to exist. If this suggestion is correct, the Pochuck deposit should be regarded as the decomposed capping of a large body of iron sulphide or pyrite."[1]

The ore is evidently of a different origin from that in the mines within the blue limestone. Not only is the ore body of a different shape but its relation to the surrounding rock is different, as is also its association with the white limestone and gneiss. If the ore was originally pyrite it should pass into sulphide below the level of permanent ground water.

In the 10th Census Report, Putnam declares[2] that the ore "is merely the outcrop of a vein of magnetite," basing this conclusion upon the fact that it contains graphite which is a frequent constituent of the magnetites of the region and upon the supposition that it occurs in the gneisses. He hazards no guess, however, as to the reason why this should be the only magnetite vein in the Highlands that is altered to a considerable depth to limonite. As a matter of fact, all the magnetites elsewhere outcrop in a fairly fresh condition, even those found south of the glacial area where weathering has been much more profound than it has been in the vicinity of the Pochuck mine. Hence it is not believed probable that the ore of this mine has originated in the magnetites.

On the other hand the alteration of pyrite into limonite is of common occurrence. Nearly all sulphide veins near the surface are altered into mixtures of oxides of which limonite is a prominent compound. This is known as "gossan" and is universally recognized as an indication of the underground presence of an iron-bearing sulphide. For example, an important belt of iron mines occurs in Virginia lying along the "Great Gossan Lead" which is the oxidized upper portion of a vein which at the level of the permanent ground water changes into pyrite. The average metallic content of the Virginia ore is between 40% and 41%, or a trifle greater than that of the Pochuck ore. The ores

[1] A. C. Spencer: Folio 161, U. S. G. S., 1908, p. 23; Folio 2, Geol. Surv. of N. J., 1908, p. 23.

[2] Vol. XV., p. 177.

of Franklin County, Pennsylvania, likewise of this origin, have been referred to in another place. (See p. 46.)

Although the evidence is not conclusive in the case of the Pochuck ore, largely because of the impossibility of studying the deposit at the present time, it nevertheless appears probable that it is an oxidized pyrite vein occuring in a fault fissure, rather than an oxidized magnetite deposit.

References: N. J. 1840, p. 90-91; 1854, p. 42; 1855, p. 146-147; 1868, p. 663; 1871, p. 32; 1872, p. 20; 1873, p. 88-89; 1879, p. 93; 10th Census, p. 176-177; Folio No. 161, U. S. Geol. S., 1908, p. 23; Geologic Atlas of N. J., 1908, No. 2, p. 23.

MINES IN THE POHATCONG VALLEY.

The Pohatcong Valley begins at the Delaware River in the vicinity of Phillipsburg and Carpentersville, runs northeast along Pohatcong Creek and terminates a short distance beyond Washington, at Karrville. It was formerly one of the important limonite-producing districts in the State, for in it were situated the Carpenter, Rapp, Riegel, Hamlen, Thatcher, New Village and Broadway mines and several explorations. The first three were of considerable importance between 1865 and 1885, but they have not been worked to any considerable extent since the last named date.

(*9, 10, 11*) The *Mines Near Carpentersville.*

The mines in the vicinity of Carpentersville, on the Delaware River, near the mouth of Pohatcong Creek, in Pohatcong Township, Warren County, are high up in the north side of the gneiss ridge that overlooks the valley of the creek.

They are among the first of those situated in the limestone that produced ore in any quantity. As early as 1868 a shaft had been sunk to a depth of 104 feet in clay and much ore had already been raised through it. This was known as the (9) Rapp mine. Later two other pits were opened to the east on what is supposed to be the same general ore body and these were called the (10) Carpenter and the (11) Riegel mines. Still later other openings were made between the Rapp mine and the Carpenter

mine. These were known as the Reese and the Boyer mines, after the owners of the land on which they were situated. All the mines are near the contact of the blue limestone with the gneiss of Musconetcong Mountain. The Rapp mine was worked quite steadily until 1885. The ore was unevenly distributed and consequently was raised from different pits at different times. In 1880 the pit then worked was 204 feet deep and the yield was 392 tons between June 1, 1879, and May 31, 1880. In 1885 a second opening was being worked. This at that time was 160 feet deep, and the ore was between one and 15 feet thick. It analyzed 45% Fe, no phosphorus and no sulphur.

At the Carpenter mine the ore is reported by Mr. Fackenthal to be in the form of a vein between a north wall of limestone and a south wall of gneiss from which the limestone was separated by five feet of clay. The vein averaged 5 feet in width and was worked about 500 feet in length down to the water level. The pits in 1880 were two in number, respectively 100 feet and 115 feet in depth. It appears from the descriptions that the ores were accumulated along the contact between the limestone and the gneiss.

In all there are nearly a dozen pits and shafts along the course of the deposit which consists of a layer of irregular pockets and lenses which dip nearly vertically. Immediately south of the deposits are outcrops of gneiss from which the ore is separated by a layer of clay. For some distance to the north nothing was encountered but clay in any of the tunnels and trenches cut into the face of the hill. In the valley at the base of the hill are outcrops of the Kittatinny limestone. There is no hard rock, except the gneiss, in the immediate vicinity of the ore bodies, but the presence of quartz in streaks and layers of chert nodules in the clay near the limonite suggests the former presence of the blue limestone. The ores are apparently along a fault zone between the Kittatinny limestone and the pre-Cambrian gniess. They are almost certainly the result of decomposition of the limestone.

A complete analysis of one of the nodules from the Rapp mine is given on page 37.

References: N. J. 1868, p. 664; 1871, p. 32; 1872, p. 21; 1873, p. 89; 1879, p. 92; 1880, p. 92; 1885, p. 105; 10th Census, p. 176.

(*12*) *Silver Hill Exploration.*

Several trial pits dug in 1879 at the base of the north slope of Silver Hill in Pohatcong Township, Warren County, uncovered ore, but so far as is known none was raised. The place was near the line of the Lehigh Valley railroad.

Reference: N. J. 1879, p. 91.

(*13*) The *Hamlen Mines.*

The Hamlen mines are about two miles east of Phillipsburg in Lopatcong Township, Warren County, near Lopatcong Creek. The first mine opened was known as the William Hamlen mine. It was originally exploited sometime in the sixties, was worked as long as the ore lasted, yielding in all about 1000 tons, and was abandoned prior to 1868. A second deposit was opened on the same property in 1868 and was worked on a small scale at intervals of a few years. It was reported as exhausted in 1874, but was later worked for yellow ocher, yielding 344 tons in the year ending June, 1880. This was found on the east side of the ore-deposit and beneath it, and had a maximum thickness of 15 feet. In this year the pit was 200 feet long and 100 feet wide. The ore and ocher were in the blue limestone.

References: N. J., 1874, p. 32; 1879, p. 92; 1880, p. 121; 10th Census, p. 176.

A second mine, the Henry Hamlen mine, was opened on an adjoining property, in 1880. Nothing is known as to its history.

References: N. J. 1880, p. 121.

(*14*) *The Thatcher Mine.*

The Thatcher or Stewartsville mine is two miles east of Stewartsville, in Franklin Township, Warren County, near the base of the Pohatcong Mountain, probably near the contact between the gneiss and the limestone. It was first worked in 1873, yielding about 5,000 tons of ore in this and the succeeding year. It was shortly afterward abandoned and remained idle until 1900, when it was unwatered and again put into shape for work. Al-

though the original excavation made in removing the ore is 200 feet long, 70 feet wide and 30 feet deep, its entire bottom, when mining was stopped, was still in ore.

The ore is said to have been of Bessemer quality; an analysis reported in 1899 gave Fe 43.64 per cent. The deposit consisted of lumps and fine granules of limonite mixed with ocher, clay and sand. The coarser portions, of which some of the lumps weighed ten tons, were limited to an "elongated pocket" or vein-like mass running northeast through the center of the deposit. This, it is conjectured, may represent the filling of an old crack from the sides of which replacement proceeded into the rock. The proportion of coarse lump ore to wash ore was large. Many of the lumps were hollow and partly filled with a coarse quartz sand and clay in which were occasional small fragments of siliceous hematite.

References: N. J., 1874, p. 31; 1879, p. 90; 1899, p. 169; 1903, p. 107.

(*15*) *The New Village Mine.*

The New Village or Cline mine is situated just west of New Village and a few rods east of the Morris Canal, in Franklin Township, Warren County, at the base of Scott's Mountain and very near the contact between the mountain gneiss and the valley limestone. It was opened in 1873 and about 400 tons of ore were raised in the succeeding year. In 1879-1880 the country around the original pit was explored by ten or more shafts, from which about 700 tons of ore were taken. The limonite was discovered to be in small pockets and therefore was expensive to work. The mine was abandoned in 1880.

References: N. J., 1873, p. 89; 1874, p. 30; 1879, p. 90; 1880, p. 121; 10th Census, p. 176.

(*16*) *The Broadway Mine.*

The Broadway mine has not been worked since 1868. Only about ten tons of ore are known to have been obtained from it before this date. The mine pit is situated at the base of Musconetcong Mountain near a mineral spring, about a mile southeast

of Broadway, in Franklin Township, Warren County, at the contact of the mountain gneiss and the valley limestone.

References: N. J., 1868, p. 664; 1874, p. 30.

MINES IN MUSCONETCONG VALLEY.

Musconetcong Valley extends from Riegelsville, on the Delaware River, to Saxton Falls, a small settlement a few miles northeast of Hackettstown. It is separated in part from Pohatcong Valley by the narrow mass of Pohatcong Mountain, but unites with this valley around both ends of the mountain.

The mines and explorations in the valley that have at one time or another produced limonites are the Wean, Slack, Hazard, Radley, Anderson and the Beatyestown mines. Of these the most important by far are the several mines comprising the group at Beatyestown. With the exception of the Wean and the Beatyestown mines all the others named are unimportant.

(17) The Wean Mine.

The Wean mine, situated one mile south of Bethlehem (or West End), in Bethlehem Township, Hunterdon County, well up on Musconetcong Mountain, alongside the road to Pattenberg, was discovered in 1875, but it was not developed as a shipping mine until several years later. Prior to 1878 it had yielded as much as 310 tons of ore per month, but this was materially reduced during 1879 and 1880, so that in the year ending June, 1880, only 565 tons of ore and ocher were raised. The total yield of the mine to the end of 1879 was about 1,500 tons. In this year the main shaft was 60 feet deep and connected with a second shaft to the southwest by a drift 200 feet long.

The ore was found in pockets and irregular masses lying upon a decomposed gneiss. In one instance it is reported as enclosed between walls of rotten gneiss. In both instances it is probable that the ore was at the base of a bed of Kittatinny limestone that lay upon the gneiss, as limestone was found in large quantity in a similar position at the north end of the Musconet-

cong tunnel of the Lehigh Valley railroad, which is but a short distance east of the mine.

About two-thirds of the ore was wash ore of a bright red color which was sold as paint. An analysis of the ore reported in 1878 gave

Fe	*P*	*S*	*Ins.*	*H_2O*	*P in 100 pts Fe*	*Authority*
55.42	.10	.10	6.90	11.80	.1807	N. J., 1878, p. 102.

References: N. J., 1874, p. 27-28; 1878, p. 102; 1879, p. 90-91; 1880, p. 120; 10th Census, p. 176.

(18) The Slack Mine.

The Slack mine is 2.5 miles east, or northeast, of Bloomsbury, Franklin Township, Warren County, near Musconetcong River. The property was explored by a shaft 8.5 feet deep, of which the last 5.5 feet and the bottom were in ore. Some ore was shipped, but in what quantity is not known. It contained:

Fe	*P*	*Mn*	*Ins.*	*P in 100 pts Fe*	*Authority*
44.33	.170	.06	21.31	.383	N. J., 1899, p. 169.

The exact position of this mine has not been identified, but it is probable that it was in the limestone near its contact with the Martinsburg slate.

Reference: N. J., 1899, p. 169.

(19) The Hazard Mine.

The Hazard mine was never an important one. It was situated about 1.5 miles west of Asbury, in Franklin Township, Warren County, near the contact between the blue limestone and the Martinsburg slates. Some ore was mined about 1877, but the place was never extensively worked.

Reference: N. J., 1879, p. 91.

(20) The Radley Mine.

The Radley mine was situated in Lebanon Township, Hunterdon County. Very little is known concerning its history or

the manner of the occurrence of its ore. It was worked in 1879 as an ocher mine, yielding about 78 tons of material that was used for paint.

References: N. J., 1879, p. 89; 1880, p. 119; 10th Census Rept., p. 176.

(21) *The Anderson Mine.*

The Anderson mine was on the road from Anderson to Port Colden, in Mansfield Township, Warren County. It is reported to have been productive previous to 1868, but to have been abandoned before that year because it became unprofitable to work.

Reference: N. J., 1868, p. 664.

(22) *The Beatyestown Mines.*

The most productive limonite deposit in the State is that which has been worked so long and profitably in the neighborhood of Beatyestown, in Mansfield Township, Warren County, on the north side of the road to Hackettstown. Openings in this ore body have been made by three different operators, under the name of the Shields mine, the Thomas mine and the Brown mine.

The ore is found in the bottom of limestone basins lying immediately upon the rock. The limestone is more ferriferous under the ore than elsewhere, a specimen obtained in 1871 yielding 82.23 per cent. of $FeCO_3$.

The Shields mine is the oldest working in the deposit. It was opened in 1868. During this year about 20 tons per day were raised. From this time until 1881 it was steadily producing, yielding in the nine years between 1872 and 1880 an aggregate of 41,121 tons. It is probable that the total amount of ore raised from the pit is greater than that raised from any other limonite pit in the State. The mine was closed shortly after 1880. Prospecting was begun again on the property in 1899, and an ore carrying 40 per cent. of iron was uncovered in payable quantity at a depth of 20 feet beneath the surface. The burden of soil and disintegrated rock that it would be necessary to move in order to get at the ore was, however, so great that no attempt was made

to work the deposit. In 1906 the mine was again opened by a shaft 65 feet deep in the bottom of the old openings, and a drift from this 65 feet long. Explorations were continued during 1907, but at the beginning of the following year the place was again abandoned.

The ore was mixed with yellow clay. About three-fourths of the material raised was lost in washing, but the portion that was saved was of excellent quality. The composition of some of this washed ore produced in 1880 was:

Fe	*P*	*S*	*Mn*	H_2O	*Authority*
42.73	0.257	0.041	1.40	8.88	10th Census, p. 176.

A complete analysis of the same sample and another of a dense nodule obtained from the workings in 1907 are given on page 37.

The walls of the pit were blue limestone, but slate ledges outcrop a short distance to the southwest.

The Thomas mine was opened north of the Shields mine. The quantity of the ore was the same as that of the Shields mine, and the relation of the deposits to the limestone was similar. The mine has never been as prolific a producer as the Shields mine, though it has yielded considerable ore. In 1880 its production was 2,050 tons.

The Brown mine adjoined the Shields mine on the south. It was opened in 1873, worked a few years and closed. It was reopened in April, 1880, and before May 31 of that year it yielded 434 tons of ore.

The ore was beneath a covering of 9 or 10 feet of soil. On the east side of the pit the blue limestone dips 60° S. E. The ore was found lying on both sides of this and resting upon it. The west side of the pit is reported to be slate. The deposit was, therefore, at the junction of the slate and limestone. The ore was mixed with yellow clay and sand and contained streaks of blue-black earth. It contained also large nodules of limestone.

References: N. J., 1868, p. 664; 1869, p. 54; 1871, pp. 32, 33; 1872, p. 21; 1873, p. 89; 1874, pp. 29-30; 1879, pp. 91-92; 1880, p. 120; 10th Census, p. 176; N. J., 1899, p. 163.

MINES IN GERMAN VALLEY.

German Valley occupies a narrow longitudinal depression in the Highlands extending from Califon northeastward a distance of about 17 miles to Wharton, where it is terminated by the southern end of Green Pond Mountain. On the east, west, and south it is surrounded by the crystalline rocks of the Highlands. The south half of the valley is occupied by the Kittatinny limestone and in this are found occasional deposits of limonite. But two mines were ever developed in the area. These were at the extreme southwest end of the valley and neither proved profitable.

The ore of one was notable because it contained large quantities of lead and zinc.

(23) *The Neighbor and Dafford Mines.*

The surface of German Valley in the vicinity of Califon in Tewksbury Township, Hunterdon County, appears to be quite generally underlain by limonite, though so far as known, the ore is not in sufficiently thick deposits for profitable working.

Ore was first discovered here in 1871 on the east side of the valley near the road running north along the foot of the Fox Hills range. Specimens of the ore contained iron as follows: 54.88 per cent.; 56.89 per cent.; 40.45 per cent.; and 56.12 per cent. During the following year the region was thoroughly explored by 100 test pits, nearly all of which struck ore, which was in small masses or concretions, mixed with yellow earth and white sandy clay. One of the pits showed a thickness of 25 feet of ore. "From these explorations it appears probable that the ore occurs in a bed or deposit quite narrow but extending for some distance lengthwise of the valley near the western base of the gneissic ridge," i. e., near the contact of the limestone and the gneiss. Explorations were continued in 1879 and 1880 proving the existence of ore upon the limestone entirely across the valley from the base of the Fox Hills on the east to the base of Schooleys Mountain on the west.

From only two points in this area, however, has ore been shipped. These are the Neighbor and Dafford mines, situated about 2 miles north of Califon near the center of the valley. Neither of these has been extensively worked, though the Dafford produced 500 tons of ore in 1879 and 1880. The Neighbor mine also yielded ore to the amount of 896 tons in 1880, but it was abandoned immediately thereafter because of the presence in the ore of 3.74 per cent. of lead and about 10 per cent. of zinc, which proved troublesome in the furnace. In later years the country around the mine was explored with a view to the development of a zinc mine, but only small scattered pockets of blende were found in the rock, of too small size to warrant working. A specimen taken from one of these pockets was reported as containing 8.429 per cent. zinc and 3.10 per cent. sulphur. A fresh specimen gave 34.76 per cent. zinc and 21.90 per cent. sulphur.

References: N. J., 1871, p. 33; 1872, pp. 21 and 22; 1879, p. 90; 1880, pp. 120 and 128; 10th Census, p. 176; N. J., 1899, p. 175.

MINES SOUTH OF THE HIGHLANDS.

At only one point in the plain south of the Highlands have explorations for ore been made, so far as the records show, and at this one comparatively little work was done. The geological conditions are not favorable for the occurrence of limonite in this area, since the Kittatinny limestone is generally absent from it.

(24) *The Bird Mine.*

The Bird mine, situated about one-half of a mile west of Clinton, in Hunterdon County, was discovered in 1873. It lies in red slate (Martinsburg slate) near its junction with the blue limestone (Kittatinny limestone). About 2000 tons of ore were raised during the year of discovery from an excavation about 20 feet deep. Only about one-quarter of the ore obtained required washing. After being worked for a short time the mine was abandoned in the same year that saw its opening. The reason

for its abandonment is not known. The result of explorations by test pitting indicates that the quantity of ore present in the vicinity is large.

References: N. J., 1873, p. 89; 1879, p. 90; 1880, p. 129.

Deposits of limonite ore are known to occur at many other points in the limestone valleys between the Highlands ridges, but so far as known, explorations to test their extent have been carried on only at the localities described above. The positions of many other deposits are indicated in the old county maps of Warren, Hunterdon and Morris counties.

CHAPTER IV.

HEMATITE.

CONTENTS.

GENERAL DISCUSSION.

CHARACTER OF THE ORE.

Appearance.—The ore known as "red hematite" is composed essentially of the mineral hematite which is the oxide of iron represented by the formula Fe_2O_3. Though very different in its appearance when obtained from different localities, the variety that occurs in New Jersey is practically all of the same kind. It is a mediumly fine-grained aggregate of dark gray or black scales and thin plates arranged in a generally parallel position, thus producing a mass with a schistose structure. Because of the glistening of the little plates caused by the reflection of light

from their flat surfaces, this type of ore is frequently known as specular ore. In a few places the New Jersey ores lack the strongly pronounced schistostity. They are then black, finely granular aggregates with a dull luster.

The red hematite is easily distinguished from the brown hematite, or limonite, by its crystalline character, its black or dark-gray color, and by the fact that it does not yield any appreciable quantity of water when strongly heated. It differs from magnetite in possessing a red streak or powder and in being non-magnetic. Although the most valuable of all the ores of iron in the United States, it is comparatively unimportant in New Jersey. It has been found at about half a dozen localities, but has been mined with profit at only one.

Composition.—Theoretically, hematite contains 70% of iron, but the ore as marketed rarely assays more than 65% of the metal. The impurities are usually quartz, apatite, and the minerals characterizing the rock with which the ore is associated. No accurate analyses of the New Jersey hematites are available. It is probable that their principal impurity is quartz and chlorite or some other magnesian silicate.

OCCURRENCE.

The occurrence of the hematites in New Jersey is practically confined to the quartzite conglomerates and shaly rocks associated with the Franklin limestone. The geological relationships are not clear. In some places the hematite appears to form the matrix of quartzites, at other places to impregnate the shaly rocks and at one place it occurs as a vein-like or dike-like mass cutting across the schistosity of certain shaly rocks that resemble sheared volcanics. In all cases it appears to be subsequent in time of origin to the rocks with which it is associated. Its mode of origin is not known, but it is probable that it was introduced by circulating water into the positions it now occupies. It is hardly likely that it is connected in any direct way with the great intrusions that forced themselves into the sedimentary beds and formed the widely prevailing gneisses of the Highlands.

Such a mode of origin would probably have resulted in many deposits, some of which would have been in the white limestone, which is much more common than the quartzite and shaly rocks associated with it. It seems more likely that the hematite was introduced before the advent of the igneous rocks, but from what source it was obtained is unknown.

Small quantities of the ore are also reported from a few localities at which the rocks associated with them are not the Franklin quartzites and conglomerates, but none of these localaties are of more than passing interest.

LOCALITIES.

Since the pre-Cambrian quartzites and shaly rocks in which the hematite deposits occur are in a few small scattered areas distributed irregularly over the western portion of the Highlands, the developments that have yielded the ore are also few and their locations widely scattered. Most of them, however, are in Sussex County.

DESCRIPTION OF INDIVIDUAL MINES.

There are two points near McAfee, in Vernon Township, Sussex County, at which hematite has been mined, but at neither place did the mining prove profitable (Fig. 3, page 60). The propositions were nothing more than large explorations. At both places the ore is associated with quartzites, conglomerates and the white Franklin limestone, but the exposures are not sufficiently abundant to warrant any definite statement as to the geological relationship of the ore.

(1) The Cedar Hill Mine.

The Cedar Hill, Smith's or the Ten Eyck mine is on the brow of the steep ridge of Franklin limestone just west of the village of McAfee. The rock west of the ore is white limestone, while that under it, i. e., on the southeast side, is a conglomerate of white quartzite pebbles in a dull reddish-green matrix, com-

posed of chlorite and amorphous hematite. This occurs in a bed 40 or 50 feet thick which can be traced for a distance on its strike of about 500 feet. It stands on edge in a nearly vertical position and is exposed to a depth of 25 feet. It is apparently intercalated with the limestone.

The conglomerate is highly ferruginous, the hematite occurring largely in the interstices between the chlorite particles that constitute its principal mass, but it is too lean to be worked as an ore. Pyrite is present in considerable quantity through the rock, and portions of it contain crystalline grains of iron carbonate (siderite) about a half-inch in diameter. These are pearl-gray on fresh fractures, but are rust-red on exposed surfaces. It is probable that the hematite may have been derived from these two minerals. The exploration was first opened about 1867. Several thousand tons were removed from two pits about 500 feet apart, but so far as known none was ever shipped. The mine was abandoned in 1872.

An analysis of a sample of the ore obtained when the mine was first opened gave:

Fe_2O_3	S	P_2O_5	SiO_2 and insol.	Met. iron	Authority.
43.3	0	.3	29.1	31.0	N. J., 1868, p. 662.

References: N. J., 1868, p. 662; 1872, p. 20; 1873, p. 89; 1879, p. 90; Folio No. 161, U. S. Geol. S., 1908, pp. 21 and 23; Folio No. 2, Geologic Atlas of N. J., 1908, pp. 21 and 23.

(2) The Simpson Mine.

The Simpson mine is 2.5 miles northeast of Hamburg and about 1 mile southwest of McAfee, on the west side of the brow of the hill overlooking the Lehigh and Hudson River Railroad. (See Fig. 3.)

The geological conditions at this mine are not essentially different from those at the Cedar Hill mine. The hill is covered with glacial drift so that exposures are very few. Several openings, however, have been made which show the quartzite conglomerate lying in layers separated by shaly material. The

iron oxide not only impregnates the conglomerate, but it occurs also as thin layers of comparatively pure hematite interleaved with the shale and quartzite, both of which are ferruginous. These dip southeast beneath beds of white limestone. On the northwest is the basal quartzite of the Paleozoic series (Hardyston quartzite), which dips to the northwest.

The mine was first opened about 1850 and before 1854 an excavation 20 feet deep had been made and 80 tons of ore had been removed from it. This is reported to have been quite pure. It was of a brownish-red color and possessed a metallic luster and a fine-grained texture. From the present appearance of the pits it is evident that considerable work has been done in more recent years, but there is no record as to its date.

References: N. J., 1854, p. 38; 1855, p. 147; 1868, p. 661; Folio No. 161, 1908, U. S. Geol. S., pp. 21 and 23; Folio No. 2, Geol. Atlas of N. J., 1908, pp. 21 and 23.

(3) The Andover Mine.

The Andover mine is in Andover Township, Sussex County, about 1.5 miles north-northeast of Andover, on the east side of the road to Pinkneyville. Here was the most extensive deposit of hematite that has been uncovered in the state. The mine produced both hematite and magnetite, but the two ores were so intermingled that it is difficult to estimate their relative importance. From the descriptions that have been handed down to us it is probable that the greater portion of ore mined was hematite. A great quantity of ore was removed, leaving a wide, gaping opening about 70 feet deep, which extends for a distance of 750 feet along the west side of a cliff of gneiss (Fig. 4).

To the west of the opening, at the southern end of the mine, is a hillock of quartzite conglomerate very much like that at the Cedar Hill and Simpson mines, and interleaved with this are indurated carbonaceous shales. The sediments have a thickness of about 90 feet and stand nearly vertical at the southwest end of the mine. In the northerly workings their dip is southeast, at some points being as low as 25°. At a few places they contained irregular masses of magnetite and hematite. Here and there the rocks are cut by pegmatite. The ore lies between these rocks and the

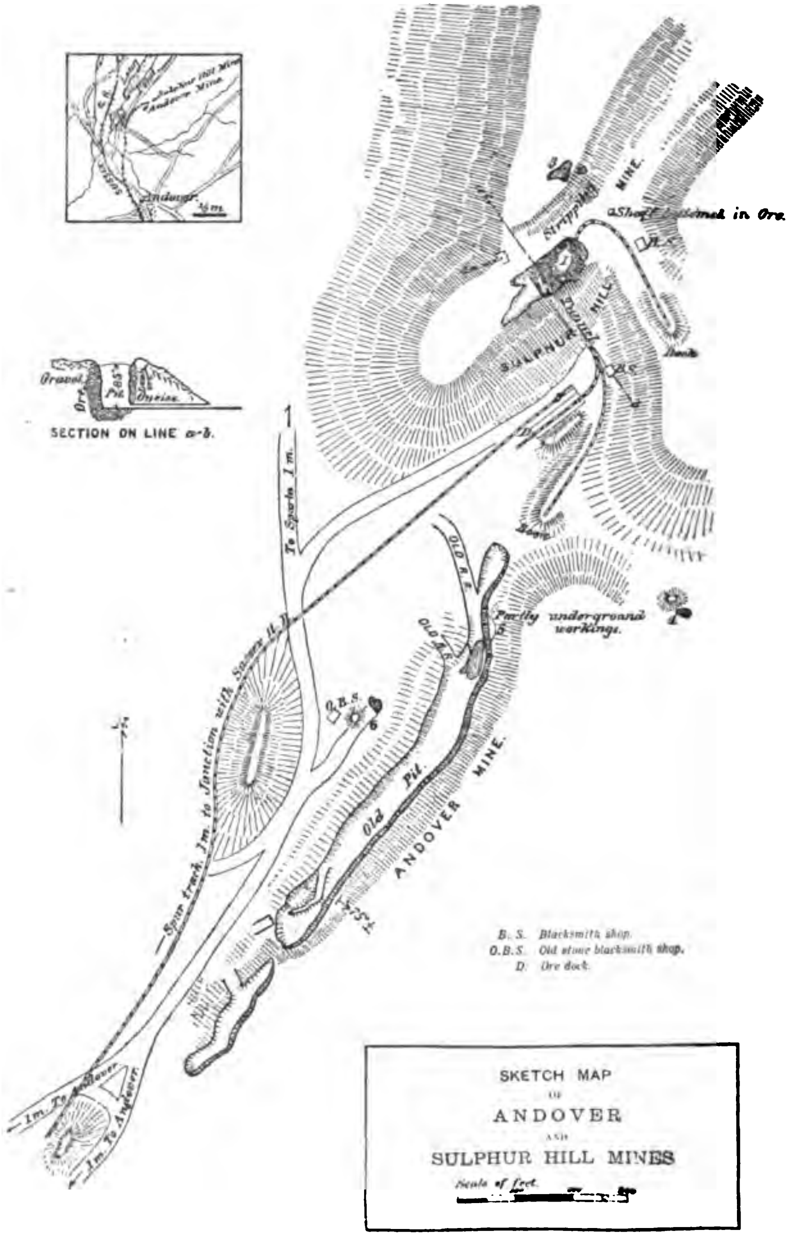

Fig. 4.

(From 10th Census Reports. Vol. XV, p. 152.)

gneiss and in irregularly shaped basins or tongues in the conglomerate. The largest of the basins measured 200 feet in length, 65 feet in width and 85 feet in depth. There is nothing to show the relations of the magnetite and hematite to one another, but from the writings of the early writers who described the mine it is evident that these relations were complicated.

There are two main workings comprising the Andover pits The larger one was at the south. This is the one referred to in the preceding paragraph. The other was north of the north end of the southern opening, and a short distance west of the projection of its trend. This second opening, which was very much smaller than the first one, is known as the Sulphur Hill mine. It produced only magnetite and consequently is included among those mines, and described elsewhere.

The southern pit, or Andover mine proper, was worked mainly from the surface. It is from 30 to 60 feet in width and very variable in depth. Its extreme length is about 850 feet. To the north the ore pitched beneath the surface and was worked underground to a distance of 200 feet or more, making the entire length of the ore body that was mined about 1,200 feet. In this northeast portion of the mine the ore was principally magnetite. The whole pit is said to have been filled with ore.

In the center of the ore mass was a "blue ore," which was characterized by its bluish-black color. In some samples examined it was granular and in others it was compact, with a black, jasper-like fracture and luster and a jointed structure. Most of the specimens were magnetic, but in others magnetite particles were scattered through a non-magnetic matrix.

Completely surrounding the blue ore was a shell of red ore which was composed of nodules of red and black hematite cemented by red hematite, or of grains of the black variety imbedded in the red variety. The mixture was essentially a red oxide of iron usually so intimately mixed with silica that the mass possessed the fracture and luster of quartz. In other places the silica appears to have been "wholly or partially in the amorphous or opaline condition and the mass has a jaspery fracture."

The red ore was thus very much like that at the McAfee localities.

Analyses of samples of these ores as given in the Geology of New Jersey, 1868, are as follows:

	Fe	*MnO*	*S*	*P_2O_5*	*Insoluble.*
1.	56.85	0.45	tr	tr	5.80
2.	58.12	0.45	0.0	0.30	6.20
3.	40.75	tr	0.0	tr	11.30
4.	44.51	0.20	0.0	0.51	11.30

1. Hematite from southwest opening.
2. Hematite with a little magnetite forming the upper part of the deposit in large mine.
3. Hematite with magnetite from northwest side of deposit in large mine.
4. Magnetite with hematite from deepest part of large mine.

The magnetite which was associated with the hematite often contained a large percentage of manganese, and consequently the iron made from the mixed ores was highly manganiferous. Analyses of specimens of the pig from the old Andover charcoal furnace and the anthracite furnace at Phillipsburg testify to this fact, and account for the excellent reputation borne by the Andover ore in the early days.

Analyses of pig iron made from Andover ore.

Analyst—P. W. Shimer[1].

	Andover.	*Phillipsburg.*
Graphite,	.101	.005
Combined Carbon,	4.529	4.212
Silicon,	.037	.294
Manganese,	5.75	3.75
Sulphur,	.003	.031
Phosphorus,	.06	.072
Iron,	89.44	91.57
	99.92	99.934

Both varieties of ore were traversed by narrow veins of calcite. The blue ore moreover, in some places, contained garnet and sphalerite particles and in it was often found considerable

[1] Trans. Amer. Inst. Min. Engin. Vol. 37, 1906, p. 198.

manganese, as stated above. In 1858 Lesley described[1] the deposit as being more shaly than previously, and stated that below the level of ground water the ore contained a noticeable amount of zinc and other sulphides, which had been found in traces only in the ore at shallower depths.

The mine was extensively worked before the Revolutionary War and the ore was smelted in the Andover furnace, which was built in 1763. During the war the mines and furnaces were taken possession of by the Continental Congress and were worked to supply the army with iron and steel. After the war the mine was abandoned until it was re-opened in 1847 by the Trenton Iron Company. It was worked until 1863, when it was again closed.

Between 1847 and 1854 about 120,000 tons of ore were taken out. The total yield of the mine (including the Sulphur Hill opening) is estimated at 400,000 tons.

References: N. J., 1854, pp. 38-41; 1855, pp. 149-163; Iron Mfrs. Guide. N. Y., 1859, p. 427; 1868, pp. 640-657; 1873, p. 88; 10th Census, pp. 151-153; Trans. Amer. Inst. Min. Engin., Vol. 37, 1906, p. 198; Folio No. 161, U. S. Geol. Survey, p. 21. Folio No. 2, Geol. Atlas of N. J., p. 21.

(4) The Byerly Openings.

The Byerly openings were made about 1873 on the west slope of a high ridge of gneiss, one-half mile southwest of the Roseville mine, in Byram Township, Sussex County. Their exact location has not been identified.

The openings, which varied in depth from 5 to 15 feet, were on a line of attraction striking northeast. Although the ore found in all the holes is described as a red hematite, which in some specimens was quite sileceous, it was in all probability a magnetite. It occurred in small lumps scattered through the earth.

An analysis of the ore found in the earth gave:

Fe=66.98; *P*=.032; *S*=tr; *Ti*=0; *Mn*=0. Authority, N. J. 1879, p. 86.

References: N. J. 1879 p. 86.

[1] Quoted by Spencer in Folio No. 161, U. S. Geol. Survey, p. 21; also in Folio No. 2, Geol. Atlas of N. J., 1908, p. 21.

(5) *The Marble Mountain Mine.*

The Marble Mountain or Fulmer's mine is situated on the southwest side of Marble Mountain, on the bank of Delaware River, about 1.5 miles northeast of Phillipsburg, in Lopatcong Township, Warren County. The mine pits are well up toward the top of the hill on the slope overlooking the river.

As at the other localities in the State at which hematite occurs the geological relationships here are also obscure. To the south of the ore pits is a great mass of yellow and light-purple shaly rocks that resemble in many respects the sheared volcanics of South Mountain in Pennsylvania. There is no evidence at Marble Mountain that the rocks are mashed volcanics but on the other hand there is little evidence to indicate any other origin for them. Some of the shales are very quartzose, others are steatic and others are very fine grained and dense, like rhyolites. In one or two places hematite replaces the dense rock locally forming nodules or rounded masses or disks which grade into the rock in all directions. In other places bands of shale are impregnated with hematite material and in one or two instances distinct bands of hematite, like veins, cut across the structure of the shaly rock. Conglomerate layers are interbedded here and there through the shales, but they are not common.

The pits in this portion of the mountain are shallow and were plainly never important. Toward the northwest the shale is replaced by a quartzitic conglomerate identical in every respect with the similar conglomerates at the Andover, the Simpson, and the Cedar Hill mines. In this a large pit has been excavated and from it much material has been removed, although from the size of the dumps observed it is probable that very little was hauled away.

The ore so far as can now be told is merely a portion of the quartzite more ferruginous than elsewhere. The hematite appears to be in the interstices between the quartz grains. The ferruginous quartzite is not in a definite bed, but it possesses irregular boundaries and on all sides grades into less ferruginous varieties. In one place it was thought folding could be detected in the quartzite and at this place the richest ore was found.

The Franklin limestone occurs both south and north of the quartzite-shale beds, but not in contact with them. It is probable that here as elsewhere the quartzite together with the shales form a part of the limestone series. The ore is probably an infiltration from some unknown source.

The mine was first opened in 1860, but the ore was found in such limited quantities that work was prosecuted for only a short time. The place was re-explored in 1880 and ore was uncovered under an area of 60 feet by 16 feet. A considerable quantity of ore reported to be of good quality was mined, but none was shipped. The mine was again explored in 1886.

The old workings consisted of a number of shallow pits and a short tunnel driven into the west side of the hill near its summit. In 1886 several new pits were dug, the largest, 25 feet square and 20 feet deep, being some 500 feet northeast of the old tunnel. The ore here was estimated to be 11 feet thick and to dip about 15° southeast, though the bedding was not distinct. About 1000 tons of ore were separated from about four times this quantity of rock. This may have been shipped, as no trace of it can now be found in the vicinity of the pit. It is reported that impure limestone was associated with the ore.

References: N. J., 1868, p. 662; 1873, p. 72; 1879, p. 90; 1880, p. 119; 1886, pp. 153-154.

(6) *Cooley's Mine.*

Cooley's exploration was in West Milford Township, Passaic County, on the west side of Greenwood Lake, at the base of Bearfort Mountain.

The ore, which was found in loose boulders scattered over the surface, is reported to have been in part limonite and in part hematite. It was inferred that hematite occurred here at the surface in connection with the conglomerates of Bearfort Mountain, because ore of this character in similar geological relations has been dug to a considerable extent at Townsend's mines, in Cornwall Township, Orange County, New York.

The place was explored to a slight extent about 1868, but no ore was found in situ. A sample, presumably obtained from one

of the boulders, is exceptional in that it contains a very large percentage of manganese.

Fe_2O_3	SiO_2 and insol.	Al_2O_3	Mn_2O_3
45.4	30.8	5.3	10.4

References: N. J. 1868, p. 662; 1879, p. 90.

(7) *The Nolf Farm Exploration.*

The Nolf Farm explorations were made in Musconetcong Mountain near the Delaware River, in Holland Township, Hunterdon County, about 1 mile from Durham furnace. The ore is reported to have been a specular hematite mixed with quartz and limonite. It occurred as boulders in the soil over an area of several acres.

Explorations were first made in 1879. In the succeeding year several shafts were sunk, but they uncovered only a thin vein of ore which was too narrow for profitable working. The mine was therefore abandoned.

An analysis of a sample reported in 1879 yielded:

Fe	*P*	*S*	*Mn*	*Ti*	*Insol.*	*Authority.*
39.07	.039	.055	0	tr	43.60	N. J., 1879, p. 90

A visit to the place indicated on the State maps as a locality for hematite showed the existence of a shallow pit on the top of the hill. On the dump nearby was a small quantity of magnetite but no hematite could be found. At the base of the hill, on a flat near the river, an old dump was detected under a growth of weeds and brush, but it contained no rock that could be identified. It was stated that the place was once important, but no definite information could be gathered as to the character of the ore obtained from it.

References: N. J., 1879, p. 89–90; 1880, p. 119.

(8) *The Titman Shaft.*

The Titman shaft was southeast of Bridgeville, on the south side of the road running along the south side of Pequest River, in Oxford Township, Warren County.

The opening, which was made in 1873, is in a gray slate lying between gneiss on the south and blue Kittatinny limestone on the north. Only a small quantity of ore was found. This is reported to have resembled the hematite of Marble Mountain.

Nothing can now be seen on the dump except fragments of slate. This is probably a slaty phase of the Hardyston (Cambrian) formation. The geological conditions here are so different from those at Marble Mountain that it is hard to believe that the ore at the two places was similar.

Reference: N. J., 1873, p. 76.

CHAPTER V.

CHARACTER OF THE MAGNETITE ORES.

CONTENTS.

APPEARANCE.

Magnetite is an oxide of iron with the composition represented by the formula Fe_3O_4. It is hard, dense, black and opaque. It crystallizes in cubes or octahedrons and is magnetic. Sometimes it becomes polarized. Then it possesses the power to attract to itself unmagnetized material, like soft iron, *i. e.*, it becomes a natural magnet. Its streak of powder is black or gray. It is easily distinguished from hematite by the color of its streak (that of hematite is red or reddish-brown) and the fact that it is attracted by even a weak magnet. Its color, crystallization and freedom from water distinguish it from limonite.

Magnetite ore as found in New Jersey is usually (1) a mixture of the mineral magnetite with varying quantities of black or dark-green hornblende and augite, colorless quartz, brown or reddish apatite, white or light-colored feldspar and sometimes black mica; or (2) of almost pure magnetite in an almost structureless mass which in many instances exhibits a distinct rectangular cleavage; or (3) of magnetite, often in octahedral

crystals, with calcite, garnet and light-green augite; and (4) of a mixture of grains of magnetite in an earthy mass of limonite containing little nodules of pyrolusite.

The first type of ore is a coarsely granular black and white rock that resembles some of the darker pegmatites and gneisses of white calcite, light-green pyroxene and red or brown garnets. masses of a purplish-black component, which is the magnetite. The second type is a dense, metallic, purple-black mass, heavy, hard and without definite structure. The third type is more varied in appearance than any of the others. It is also granular like the first type, but the magnetite is scattered through a matrix of white calcite, light-green pyroxene and red or brown garnets. The fourth type is an ocherous, earthy mass through which are scattered crystalline lumps of a hard, heavy magnetite.

The first two types are characteristic of ores associated with the gneisses and the last two of those in the Franklin limestone.

CHEMICAL COMPOSITION.

The chemical composition of the pure mineral magnetite is Fe=72.4; O=27.6%. A few of the magnetic ores of New Jersey approach this composition, but none quite reach it. There is always more or less hornblende or pyroxene, pyrite and apatite mingled with the magnetite as it is prepared for market, and consquently there are always present some silica, lime, magnesia, alumina, sulphur and phosphorus. Certain classes of ores, notably those of the Franklin limestone, contain manganese, and others a greater or less quantity of titanium. Some quantities of soda, potash and the heavier metals are probably nearly always present, but they have rarely been reported in analyses because they have rarely been sought for.

Quite a number of the mines have at one time or another placed upon the market ore that has contained more than 62 per cent. of the metal. The majority, however, have furnished ore ranging between 50 per cent. and 60 per cent. of iron, and in good times a few ores have been shipped in which the iron content has been as low as 40 per cent. These figures do not necessarily indicate that the ore as mined varies greatly in composition. They

are evidence, rather, that some producers have taken greater care in preparing their ore for shipment than have others Much of the product of the mines is unsalable as mined. By careful cobbing, however, or by magnetic treatment, a part of the silicate minerals is removed and the magnetite is thereby concentrated. With the removal of the hornblende and augite much of the magnesia is abstracted from the ore and with the removal of quartz much of the silica is taken out. The remaining constituents are not especially objectionable with the exception of the sulphur, the titanium and the phosphorus. These are diminished somewhat by magnetic concentration. The sulphur may be more completely removed by roasting. The titanium and phosphorus, when originally present, may continue in the ore after the most careful treatment, and may injure its value in the open market. Fortunately titanium is a comparatively rare constituent in large quantity. Phosphorus, on the other hand, is constantly present as the mineral apatite. In a few instances it is present in such large quantity that serious attempts have been proposed to utilize it as a phosphate in the manufacture of fertilizers.

It is naturally impossible to estimate the average quality of the ore as it is obtained from the mines, as practically all of it is concentrated to some degree before shipment. We have, however, on record a large number of commercial analyses of samples that represent shipments or stock piles, and these give us some idea as to the quality of ore that it has been thought practicable and economical to place upon the market. In other words, they represent the quality of ore that can be furnished at the prices which obtained at about the time the analyses were made. Upon referring to the figures below it will be seen at once that many of the earlier analyses are unreliable with respect to the determination of titanium, phosphorus and sulphur. When the analyses are indicated as having been made at different times, the later ones should be regarded as the most trustworthy. This is especially true of titanium, as in the years before 1879 no attempt was made to discover whether this element was present or not. We know now that the mineral sphene is almost universally present in the magnetites of the State, so that some titanium should be found in nearly all analyses.

Very few ores of the State have been subjected to complete chemical analysis. In a number of instances, however, partial analyses have been made that include all of the components of most interest to the furnace operators, and in connection with the work of the 10th Census and that of the U. S. Geological Survey a few additional analyses are reported that embrace all the constituents. These and others that are published here for the first time are the only analyses, so far as is known, that attempt to show in detail the exact composition of the ores.

The complete analyses made by the chemists of the 10th Census, of the U. S. Geological Survey, and by Mr. R. B. Gage, the present chemist for the State Survey, are regarded as being accurate. Of the partial analyses published in the State Reports, many of those of earlier date bear on their face evidence of their unreliability. The later ones are more trustworthy. Most of them may be considered as close approximations to the facts. The partial analyses furnished by the furnace laboratories are presumably accurate with respect to iron, sulphur and phosphorus, but some of them are unreliable with respect to the other constituents. The values of the analyses given below may be inferred with considerable certainty from their dates of publication and their summations.

The analyses are arranged in several tables—those of the ores occurring in the limestone being separated from those of the ores associated with the gneisses. The titles of the tables sufficiently indicate their contents. Under the caption "Authority" are recorded the sources from which the records of the analyses were taken.

Commercial Analyses.—The tables of commercial analyses include all analyses of the magnetite ores of the State that have been published and a few that have been furnished by the chemists of various blast furnaces. The earlier ones are notably poor, as will be seen from the fact that there is often no record of sulphur in ores which by later analyses are found to contain a large quantity of this element. It must be remembered, however, that in the case of mines south of the glaciated area the ore near the surface usually contains much less sulphur than that at greater depths.

Table XIII.—Commercial Analyses of Magnetites from the Franklin Limestone.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Ahles,	Coarse ore,	56.13	tr	.02	2.65	tr	H_2O=3.91[1],	.000	E. C. Sullivan, 1905.
	Coarse ore, dried at 212°,	57.01	tr	.02	2.69	tr	H_2O=2.59,	....	
	Fine ore,	35.75	.14	.08	7.13	tr	H_2O=12.29[3],	.391	E. C. Sullivan, 1905.
	Fine ore, dried at 212°,	37.58	.15	.084	7.52	tr	H_2O=7.55,	....	
	Whole ore[4],	48.60	....	....	4.12	....	H_2O=6.26[3],	....	
	Whole ore, dried[4] at 212°,	47.65	.092	.038	2.351	....	Combined H_2O,	.193	N. J. 1904, p. 295.
Albertson,		55.60	....	....	3.30	....	H_2O=5.00,	....	N. J. 1874, p. 58.
Howell Farm,		58.50	.05	.43	.50	0	C=.70, CO_2=4.63, CaO=4.82,	.070	N. J. 1873, p. 86.
	Brownish-black, earthy ore. W. side of vein,	57.17	.26	tr	2.09	0	Graphite & Dolomite,	.456	N. J. 1878, p. 101.
	Hard, earthy, blue-black ore. Middle of vein,	53.05	.37	1.24	1.39	0	Graphite, CaO=3.71,	.698	N. J. 1878, p. 101.
	Hard, brown-black ore. E. side of vein,	50.72	.19	.18	2.02	0	CaO=6.49, MgO=1.30,	.376	N. J. 1878, p. 101.
Inshow Lot,		51.40	.017	.00	.79	....		.033	N. J. 1879, p. 84.
Little (Fellows),	Shipment, 1891[5],	62.25	....	....	....	....		....	N. J. 1899, p. 167.
	Shipment, 1891[6],	55.34	....	....	....	....		....	N. J. 1899, p. 167.
	Shipment, 1893[7],	56.29	.103	....	....	....		.183	N. J. 1899, p. 167.
	Washed ore[8],	37.94	....	....	....	....		....	N. J. 1899, p. 167.
	Black ore[9],	67.54	.020	.08	.90	tr		.029	N. J. 1899, p. 169.
	Washed ore (?),	68.60	.044	.10	.77	....		.064	N. J. 1873, p. 75.
Osmun,	Shipment[10],	58.302	.033	....	1.084	....		.056	N. J. 1899, p. 168.
	Shipment[10],	55.73	.065	....	....	....		.117	N. J. 1899, p. 168.
Pikes Peak,	Shipment, 1880,	33.15	.033	.439	.225	0		.099	10th Census, p. 154.
	1 sample,	57.196	0	0	2.71	0	Contains C, H_2O, CO_2 CaO, MgO, etc.,	..	N. J. 1868, p. 659.

Table XIII.—Commercial Analyses of Magnetites from the Franklin Limestone.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Queen,	Shipment of 343 cars, 1892,	55.29	....	....	....	....		....	N. J. 1899, p. 167.
	Shipment of 16 cars, 1893,	55.12	.229	....	....	....		.417	N. J. 1899, p. 167.
	Stock pile[11],	54.35	1.520	....	1.264	....		2.796	N. J. 1899, p. 167.
Raub,	Coarse ore,	63.87	.118	....	.512	....		.185	N. J. 1899, p. 168.
	Fine ore,	33.80	.192	....	1.836	....		.568	N. J. 1899, p. 168.
	Surface ore,	49.34	.109	....	5.809	....	H_2O & Org=13.55,	.221	N. J. 1873, p. 75.
Riddle,		34.72	.008	.584	.35	.19		.023	N. J. 1899, p. 166.
Roseville,		50.61	.00	.40	....	....		.00	N. J. 1868, p. 629.
	50 tons sorted ore,	53.92	.035	.013	....	....		.065	10th Census, p. 151.
Stinson,	Sample,	63.12	.017	.00	.65	....	Contains garnet,	.027	N. J. 1879, p. 85.
	Sample,	60.66	.006	tr	.40	....	and	.010	N. J. 1879, p. 85.
	Sample,	49.79	.02	.00	2.74	....	calcite,	.040	N. J. 1879, p. 85.
Sulphur Hill,	N. & W. sides of pit,	42.63	.024	2.290	.25	.08		.056	10th Census, p. 151.
	Cobbed ore,	36.91	.022	2.527	+	+		.060	10th Census, p. 151.
	Roasted ore,	46.53	.020	.786	....	....		.043	10th Census, p. 153.
	Soft brown streaks in hard magnetite,	32.73	.100	.270	+	+		.306	10th Census, p. 151.

[1] Total water, of which 1.36% can be driven off at 212°.

[2] Total water, of which 5.13% can be driven off at 212°.

[3] Total water, of which 2.415% can be driven off at 212°.

[4] Whole ore consists of a mixture of 28% of fine ore and 72% of coarse.

[5] Shipment of 25 cars in 1891.

[6] Shipment of 375 cars in 1891; including 10 cars of unwashed ore.

[7] Shipment of 531 cars in 1893; probably washed ore.

[8] Shipment of 2 cars in 1891.

[9] Shipment to Cooper & Hewitt; washed ore.

[10] Shipment of 4 cars to Cooper & Hewitt; probably washed ore.

[11] Sample from stock house at Hellertown, Pa., in 1893; probably washed ore.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Allen,	Shipment, 1880.	56.99	.593	....	....	....		1.041	10th Census, p. 171.
Andover,	Opening on hill, E. of N. end of pit,	62.31	.001	.059	+	+		.002	10th Census, p. 151.
	Old pillar, N. end of pit,	63.62	.018	.057	+	+		.028	10th Census, p. 151.
	Small opening, W. of pit,	41.66	.110	.071	+	+		.265	10th Census, p. 151.
Baker (Mine Hill),	Shipment, 1880,	32.02	.033	....	....	....		.103	10th Census, p. 169.
Bald Pate,	Stock pile, fine earthy ore,	54.10	.039	.025	....	....		.072	10th Census, p. 159.
Barker or Bulgin,		61.94	tr	.00	.00	.88		tr	N. J. 1880, p. 126.
Bayard,		49.50	tr	....	....	3.60		tr	N. J. 1875, p 35.
Beach Glen,	Shipment, 1880,	48.63	.025	....	....	....	Cr,	.051	10th Census, p. 172.
	Ore, crude,	41.75	.0643	....	....	....		.154	N. J. 1886, p. 137.
	Concentrated,	65.50	.0224	....	....	....		.0342	N. J. 1886, p. 137.
	Sample,	37.9	tr	.00	....	....		tr	N. J. 1868, p. 556.
Beemer,	Red ore,	54.23	.078	....	....	....		.144	N. J. 1899, p. 167.
	Blue ore,	41.10	.135	2.958	....	....		.329	N. J. 1899, p. 167.
Beers,	Sample,	54.46	.04	.31	.00	4.70		.073	N. J. 1878, p. 99
Bishop,	Shipment,	65.87	.092	.391	.00	1.19		.140	Privately communicated.
Old Blue,		67.38	.025	....	....	....		....	N. J. 1873, p. 54.
Bloom,		37.5	tr	tr	....	2.86		tr	N. J. 1875, p. 35.
Brotherton,	Shipment, 1880,	50.98	.214	....	....	+		.420	10th Census, p. 168.
	Sample,	65.00	tr	.00	....	....		tr	N. J. 1868, p. 567.
Brown or Kanouse,	Surface,	46.00	.03	2.08	....	....		.065	N. J. 1874, p. 22.
Bryant,	Slope No. 1,	63.24	.038	....	....	+		.060	10th Census, p. 167.
	Shaft No. 2,	50.70	.025	....	....	+		.049	10th Census, p. 168.
Byram,	Shaft No. 7,	33.52	.393	....	....	+		1.020	10th Census, p. 168.
	Shaft No. 12,	28.24	.605	....	....	+		2.142	10th Census, p. 168.
	Shaft No. 6, run of pit,	40.70	.790	....	....	....		1.940	10th Census, p. 168.
	Shaft No. 6, band of rich ore,	59.54	.245	....	....	....		.441	10th Census, p. 168.
	Sample,	64.1	tr	.00	....	....		tr	N. J. 1868, p. 569.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Old Byram,	Pillar,	57.75	2.110	....	....	....		3.653	10th Census, p. 168.
Budd or Wright,	Red ore,	49.88	.342	1.382	....	....		.685	10th Census, p. 158.
	Blue ore,	47.62	.521	2.824	....	....		1.094	10th Census, p. 158.
Byerly Openings,	Red ore,	66.98	.032	tr	0	0		.048	N. J. 1879, p. 86.
Canfield's Phosphate,		39.10	6.51	.03	....	....		16.65	N. J. 1871, p. 35.
Canistear,	Shipment, 1880,	35.38	.084	.942	....	....		.237	10th Census, p. 154.
Cannon,	No. 1,	46.30	2.43	....	....	.49		5.25	N. J. 1873, p. 53.
	No. 2,	53.41	2.88	....	....	.43		5.39	N. J. 1873, p. 53.
	No. 3,	67.44	tr	....	....	.43		tr	N. J. 1873, p. 53.
	No. 4,	63.53	tr	....	....	1.66		tr	N. J. 1873, p. 53.
	Shipment, 1880,	55.25	1.567	....	....	....		2.818	10th Census, p. 174.
	Dump,	58.61	.296	.026	....	....		.505	N. J. 1899, p. 170.
Car Wheel,	Vein,	54.84	.151	.225	+	....		.275	10th Census, p. 160.
	Stock pile,	50.14	.25	.234	.20	....	SiO_2=17.46, CaO=7.20,	.50	Empire Steel & Iron Co.
		68.83	.013	.100	....	....	Al_2O_3=1.70, MgO=4.12,	.020	
Centennial or Squiers,	Surface,	48.16	.14	3.02	0	....		.29	N. J. 1876, p. 53.
	Deep,	55.39	.067	1.74	0	0		.121	N. J. 1876, p. 53.
Charlotteburgh,	Stock pile,	58.15	.151	....	....	....		.260	10th Census, p. 174.
	Pit,	61.420	.021	.274	....	....		.034	N. J. 1878, p. 98.
	Pit, near Green Pond R. R.,	61.470	.028	3.360	....	....		.046	N. J. 1878, p. 98.
	Pit, near Green Pond R. R.,	67.420	.014	.550	....	....		.021	N. J. 1878, p. 98.
	Lamellar ore from hill E. of old mine,	64.940	tr	.390	....	.610		tr	N. J. 1878, p. 98.
	Sample, old mine,	65.9	tr	tr	....	....		tr	N. J. 1868, p. 596.
	Side hill run,	53.2	0	0	....	....		....	N. J. 1868, p. 596.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Chester,		66.2	.32	....	0	....	SiO_2=2.65,	....	Private Comunication.
Church,	See Van Syckles.								
Cobb,	Calcined and crushed,	59.79	.426	....	....	....		.712	10th Census, p. 174.
Combs,	Stock pile, 1880,	37.15	.036	....	....	+		.097	10th Census, p. 174.
Cooper, at Chester,	Surface ore, washed,	62.89	.156	....	....	+		.248	10th Census, p. 166.
	Red ore,	66.33	.078	0	0	....		.118	N. J. 1880, p. 177.
	Blue ore,	61.59	.047	4.62	0	....		.076	N. J. 1880, p. 177.
	Blue ore,	59.91	.066	3.50	....	....		.111	N. J. 1884, p. 79.
Cooper, at Ringwood,		59.72	2.71	tr	.15	+		4.517	N. J. 1873, p. 54.
Corwin,		61.4	.2	.6	....	....		.33	N. J. 1868, p. 576.
Cramer,	No. 1,	62.23	.14	0	tr	5.97		.226	N. J. 1877, p. 49.
	No. 2,	40.25	.39	?	tr	2.56		.97	N. J. 1877, p. 49
Cromwell,		50.53	....	2.00	....	....		....	N. J. 1886, p. 139.
Cummins,	Washed ore,	56.54	tr	2.80	1.77	0		tr	N. J. 1881, p. 38.
Dalrymple,	Stock pile, No. 9 shaft,	59.54	.366	....	....	+		.615	10th Census, p. 167.
	Shipment,	54.064	.25	tr	....	+	SiO_2=18.00,	.462	N. J. 1899, p. 161.
	Stock pile, No. 5 shaft,	55.92	.222	....	....	+		.397	10th Census, p. 167.
Davenport,	Stock pile,	47.76	.398	.208	....	....		.833	10th Census, p. 155.
Day,		50.88	.083	tr	.35	3.05		.163	N. J. 1880, p. 126.
DeHart,	Stock pile,	50.70	.633	....	....	+		1.248	10th Census, p. 167.
DeKay Farm,	Sample,	45.75	.110	.41	....	2.81		.230	N. J. 1899, p. 162.
Denmark,	Stock pile,	49.76	.056	....	....	....		.113	10th Census, p. 172.
Dickerson,	Main vein,	61.62	1.186	....	....	....		1.924	10th Census, p. 169.
	Bottom,	65.17	.282	....	....	....		.433	10th Census, p. 169.
	Side vein,	63.63	.178	....	....	....		.279	10th Census, p. 169.
Dodge,	Shipment, 1880,	50.70	.168	.443	....	....		.331	10th Census, p. 156.

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Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Duckworth Farm,		64.32	.004	....	....	....		.006	N. J. 1879, p. 63.
Edison,	Briquettes, 1889,	62.83	....	....	....	....		....	N. J. 1899, p. 170.
Egbert Church,	Stock pile,	47.37	.418	....	....	....		.882	10th Census, p. 159.
Elizabeth,		61.822	....	tr	tr	....		....	N. J. 1899, p. 154.
	Shipment, 1880,	57.67	.971	....	....	....		1.683	10th Census, p. 172.
Evers,	Shipment, 1880,	47.86	.086	....	....	+		.180	10th Census, p. 167.
Ford,	Stock pile,	50.70	.313	.753	....	....		.617	10th Census, p. 156.
	Shipment, 1899,	53.89	.319	.498	....	....		.594	N. J. 1899, p. 169.
	Shipments,	46.87–52.76	....	....	....	....		....	N. J. 1899, p. 169.
Fox Hills (Fisher Mine),		57.50	.04	.59	o	tr	SiO_2=11.90,	.07	N. J. 1879, p. 46.
Green Pond,	Shipment, 1880,	51.33	.033	....	....	....		.064	10th Census, p. 174.
Hacklebarney,	River slopes,	52.03	.03	2.33	....	o		.06	N. J. 1873, p. 36.
	Open cut,	59.21	.08	3.78	....	o		.14	N. J. 1873, p. 36.
	Run of ore, S. W., hill,	47.21	.98	3.290	....	....		.207	10th Census, p. 165.
	Coal house pit,	56.59	.025	3.653	....	....		.044	10th Census, p. 165.
	S. W. side river, washed surface ore,	48.38	.057	.529	....	....		.118	10th Census, p. 165.
	Andrews open cut, N. E. side river,	52.00	.048	3.763	....	....		.092	10th Census, p. 165.
	Hill, N. E. side river,	46.47	.075.	3.517	....	....		.161	10th Census, p. 165.
	S. W. hill, open cut,	55.72	.032	3.29	....	....		.059	N. J. 1879, p. 48.
	Andrews cut,	57.46	.033	3.42	....	.		.058	N. J. 1879, p. 48.
	Birch tree opening,	53.75	.036	3.33	....	....		.066	N. J. 1879, p. 48.
	Wiggins open cut,	57.68	.025	2.66	....	....		.044	N. J. 1879, p. 48.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Hager,		56.13	.29	7.59	.00	.84		.52	N. J. 1879, p. 63.
	Stock pile,	62.71	.274	.093	....	....		.437	10th Census, p. 164.
		56.39	.19	....	....	4.28*		.34	N. J. 1899, p. 165.
Haggerty Farm,		58.55	.33	.05	....	2.56		.551	N. J. 1879, p. 76.
	Northern opening,	56.40	.21	.05	....	....		.38	N. J. 1876, p. 52.
Hann,		56.970	.367	.088	.00	.640		.636	N. J. 1879, p. 67.
Hard,		63.27	.81	.01	.23	.24		1.28	N. J. 1873, p. 54.
Hedges,		53.00	.45	2.46	....	....		.85	N. J. 1873, p. 37.
Henry Tunnel,		26.984	.042	....	.31	....	H_2O=1.20,	.155	N. J. 1873, p. 79.
Hewitt,	Shipment,	52.33	.078	3.324	....	....		.149	10th Census, p. 174.
		48.88	.08	4.54	.12	....		.170	N. J. 1873, p. 54.
Hibernia,	Average of shipment of Glendon & DeKamp or Upper Wood, 1880,	53.75	.364	....	....	....		.677	10th Census, p. 173.
	See, also, Scott, Lower Wood & Wharton.								
Hill,	Stock pile,	27.88	.045	.267	....	....		.161	10th Census, p. 153.
High Bridge,	Taylor pit,	55.15	.609	5.172	....	....		1.104	10th Census, p. 164.
	See also Cromwell.								
Hoit Farm,		61.69	.026	1.23	.43	.79		.042	N. J. 1873, p. 80.
Hope,	Hillside pit,	62.66	.458	....	....	....		.731	10th Census, p. 174.
	Bottom of hill,	63.20	.448	....	....	....		.709	10th Census, p. 174.
	Old mine,	66.03	.20	....	.19	.18		.303	N. J. 1873, p. 54.
	New mine,	68.30	.21	....	.27	.32		.301	N. J. 1873, p. 54.
Horton, David,		49.57	1.30	....	....	.66	H_2O=.40,	.259	N. J. 1873, p. 40.

* Other analyses give 2.49 and 3.44.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Hude,	Small opening W. side of hill,	49.95	.037	.178	....	....		.074	10th Census, p. 158.
	Stock pile,	50.23	.057	1.220	....	....		.113	10th Census, p. 158.
		53.77	.084	1.342	....	....	MoS=und.,	.175	N. J. 1901, p. 138.
Huff,	Selected sample,	54.19	1.33	tr	....	.46		2.45	N. J. 1880, p. 106.
Hurd (Wharton),	Shipment,	57.11	1.618	....	....	....		2.833	10th Census, p. 170.
		61.750	1.229	.213	tr	....	SiO_2=3.930, CaO=4.21, MgO=1.868,	1.99	Lab. Wharton Fur. 1905.
Hurd (Hurdtown),	Shipment, 1880,	66.02	.196	.169	tr	.08		.255	10th Census, p. 157.
	1875,	62.95	.209	.06	.15	....		.336	N. J. 1885, p. 105.
	1875,	66.63	.192	.02	.16	....		.288	N. J. 1885, p. 105.
Jackson or Pompton,		52.96	.226	.06	....	2.68		.440	N. J. 1873, p. 27.
Kahart,		52.34	.17	1.23	....	.854		.329	N. J. 1873, p. 26.
Keeler,		54.96	1.48	.01	.19	.88		2.83	N. J. 1873, p. 54.
Kishpaugh,	Average shipments,	55.91	.037	....	....	....		.066	N. J. 1885, p. 106.
	Average shipments,	54.25	.128	.05	.39	+	H_2O=1.64,	.236	N. J. 1873, p. 83.
	N. E. slope,	49.68	.036	.755	+	+		.072	10th Census, p. 149.
	S. W. slope,	54.71	.036	.542	+	+		.066	10th Census, p. 149.
	Cook farm, 1896,	48.516	.042	.930	....	....		.194	N. J. 1899, p. 160.
Lanning,		53.29	.00	.265	.489	.00		.000	N. J. 1881, p. 37.
Lawrence,		51.62	.246	....	....	+		.477	10th Census, p. 167.
Lebanon,		41.50	1.66	2.74	....	.29		4.00	N. J. 1899, p. 166.
		45.075	1.625	3.634	....	....		3.605	N. J. 1899, p. 166.
Lower Wood,	Shipment, 1880,	56.00	.223	....	....	....		.398	10th Census, p. 173.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Losey Opening,	Light ore,	38.430	.028	.140	.625	....		.073	N. J. 1881, p. 39.
	Dark ore,	44.10	.05	1.64	.48	....		.115	N. J. 1881, p. 39.
Lurk,	Shipment,	64.482	....	....	....	....		....	N. J. 1904, p. 296.
	Other samples, same shipment,	54.016–58.405	....	....	....	....		....	N. J. 1904, p. 296.
	Selected sample,	66.534	.099	....	....	....		.149	N. J. 1904, p. 296.
Marsh,	Sample,	57.620	.167	.055	.00	1.250		.29	N. J. 1879, p. 69.
Martin,		49.25	.25	.00	....	.61		.51	N. J. 1878, p. 100.
McKean,	Stock pile,	46.6	.03	.22	.23	tr		.07	N. J. 1874, p. 28.
McKinley,	Slope No. 3, see, also, New Mine,	51.24	.28	.15	.22	.36		.550	N. J. 1903, p. 100.
Millen,	Shipment, 1880,	43.73	.583	....	....	....		1.333	10th Census, p. 169.
Miller,		59.36	2.07	....	.19	.31		3.487	N. J. 1873, p. 53.
Mt. Arlington,		43.18	.213	.783	....	....		.493	N. J. 1899, p. 170.
Mt. Hope,	Shipments,	63.00	.70	tr	0	....	Al_2O_3=1.70, CaO=3.00, MgO=1.10,	1.111	Empire S. & I. Co., 1905.
	Brannin vein,	60.81	1.230	....	....	....		2.023	10th Census, p. 172.
	Elizabeth vein, shipment,	57.67	.971	....	....	....		1.683	10th Census, p. 172.
	Jugular vein, shipment, 1880, see, also, Taylor Mine,	58.77	1.177	....	....	....		2.003	10th Census, p. 172.
	Teabo vein, across stope, see, also, Elizabeth,	60.61	.577	....	....	....		.952	10th Census, p. 172.
Mt. Olive,	Stock pile,	58.92	.182	1.960	....	....		.309	10th Census, p. 161.
	Surface ore,	63.36	.090	.145	....	....		.142	10th Census, p. 161.
Mt. Pleasant,	Shipment, 1880,	64.86	.185	....	....	....		.285	10th Census, p. 171.
		66.00	.196	....	....	....		.298	N. J. 1886, p. 148.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Naughright,	Blue ore,	64.77	.07	.27	....	4.57		.11	N. J. 1878, p. 100.
	Gray ore,	59.32	1.11	.41	.23	3.90		1.88	N. J. 1878, p. 100.
New Mine,	Before hand picking,	39.54	.044	.758	+	+		.111	10th Census, p. 160.
	Stock pile,*	43.31	.072	.307	+	+		.166	10th Census, p. 160.
	Average of week's output,	46.66	.095	.270	+	....		.204	10th Census, p. 160.
	Sample,	66.77	.013	.10	.23	.00		.196	N. J. 1873, p. 61.
Orchard,	Shipment,	55.00	1.722	....	....	....		3.130	10th Census, p. 170.
Oxford,	See Carwheel, Lanning, McKinley, New, Washington & Welch.								
Pardee,	Stock pile,	59.23	1.067	.113	.26	.05		1.801	10th Census, p. 155.
Peters,	Shipment, 1880,	55.56	1.556	....	....	....		2.801	10th Census, p. 174.
		63.96	.39	....	.19	.18		....	N. J. 1873, p. 54.
Petty,		54.37	.02	.00	.18	.0	NiO=.63,	.038	N. J. 1899, p. 166.
Pequest,		48.84	tr	....	.19	....	H_2O=1.950,	tr	N. J. 1873, p. 78.
Pikes Peak,	See Stony Brook.								
Pitney,	Washed, soft, red,	50.84	.112	.142	....	....		.220	10th Census, p. 164.
Randall Hill,	Shipment, 1880,	44.51	.577	....	....	....		1.296	10th Census, p. 169.
Richard,	Shipment, Shaft No. 3,	62.32	.661	....	....	....		1.061	10th Census, p. 171.
	Shipment, Shaft No. 6,	58.05	.851	....	....	....		1.465	10th Census, p. 171.
	Shipment, Shaft No. 7,	61.43	.881	....	....	....		1.434	10th Census, p. 171.
Ringwood Mines,	See Blue, Cannon, Cooper, Hard, Hewitt, Hope, Keeler, Miller, Peters, Snyder and St. George.								

* Mixed ore from "Carwheel" and "Gray ore" veins.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Roberts,	Across E. stope,	63.91	.613	.133	....	....		.959	10th Census, p. 155.
	Across W. stope,	64.22	.746	.105	....	....		1.162	10th Census, p. 155.
Samson,	Stock pile,	51.39	.097	4.158	....	....		.188	10th Census, p. 166.
	Stock pile,	53.90	.110	3.80	....	....		.206	N. J. 1884, p. 77.
Scott,	Across N. W. vein,	58.22	.407	....	....	....		.699	10th Census, p. 173.
	Across S. E. vein,	57.27	.139	....	....	....		.243	10th Census, p. 173.
Shafer,		45.22	.09	.028	tr	3.02		.31	N. J. 1879, p. 75.
Sickles,	Stock pile,	38.11	.050	.976	....	....		.131	10th Census, p. 158.
Silver,		54.2	....	34.4	....	....		....	N. J. 1868, p. 621.
Skellinger,	See Samson.								
Snyder,		49.61	.06	.20	....	....		.121	N. J. 1873, p. 54.
Splitrock,	East vein,	63.399	.0109	.068	....	.0		.157	N. J. 1879, p. 58.
Squires,	Surface,	48.16	.14	3.02	.00	.00		.29	N. J. 1876, p. 54.
	Deep,	55.39	.067	1.74	.00	.00		1.21	N. J. 1876, p. 54.
Stirling,	Shipment, 1880,	58.80	1.342	....	....	....		2.282	10th Census, p. 170.
St. George,		66.45	1.09	....	.15	.40		1.641	N. J. 1873, p. 53.
Stockholm,		67.10	tr	.61	3.74	2.19		tr	N. J. 1881, p. 38.
Stony Brook or Pikes Peak,		64.69	tr	.00	.00	.91		tr	N. J. 1876, p. 54.
Stony Brook or Pikes Peak,		63.45	tr	2.03	....	.18		tr	N. J. 1880, p. 109.
Stoutenburg,		60.13	.839	.10	....	.43		1.394	N. J. 1873, p. 58.
	Stock pile,	56.37	.639	.155	....	....		1.134	10th Census, p. 162.
Swayze (at Chester),		59.21	.08	1.59	tr	.0		.136	N. J. 1873, p. 34.
Taylor,	Mt. Hope, 1895,	57.22	.863	.030	tr	....	SiO_2=9.12, CaO=1.92, Al_2O_3=2.20, MgO=51	....	Private communication.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
Teabo,	From foot wall 200 ft. in depth,	64.00	.13	.00	....	....		.20	N. J. 1868, p. 588.
	From hanging wall 200 ft. in depth,	54.6	.57	.00	....	....		1.04	N. J. 1868, p. 588.
	Sample, 1876 No. 1,	50.145	.707	.102	....	....		1.410	N. J. 1885, p. 102.
	Sample, 1876 No. 2,	51.993	.463	.010	....	....		.890	N. J. 1885, p. 102.
	Shipment, 1880,	59.31	.468	....	....	....		.789	10th Census, p. 171.
Ten Eyck or Welling,		33.91	.028	....	....	....		.084	N. J. 1876, p. 53.
	Sample,	54.23	.033	tr	.00	....		.061	N. J. 1879, p. 81.
Topping,	Red surface ore, stock pile,	55.84	.086	.00	....	....		.154	10th Census, p. 166.
VanSyckles or Church,		50.39	tr	1.21	.00	7.08*	V_2O_5=.31—.38,	tr	N. J. 1873, p. 55. N. J. 1899, p. 165.
Washington,	Across stope,	57.43	.505	.620	+	+		.879	10th Census, p. 161.
	Shipment, 1880,	61.36	.657	.609	+	+		1.070	10th Census, p. 161.
		63.19	.615	1.68	....	....		.972	N. J. 1885, p. 106.
	Raw ore,	59.54	.43	4.00	.07	.10		.722	N. J. 1903, p. 101.
	Roasted ore,	59.53	.427	.375	.11	.10		.719	N. J. 1903, p. 99.
Washington Forge,	Stock pile,	57.39	1.261	....	....	....		2.197	10th Census, p. 170.
	Sample,	61.84	.633	.245	.00	.00		1.022	N. J. 1880, p. 107.
Waterloo,		65.6	tr	.00	....	....		tr	N. J. 1868, p. 628.
Welch,	Shipment,	46.59	.077	.342	+	+		.165	10th Census, p. 160.
	Week's output,	41.60	.059	.585	....	....		.142	10th Census, p. 160.
Weldon,	Stock pile,	54.80	.554	.266	....	....		1.010	10th Census, p. 157.
Welling,	See Ten Eyck.								

* Other analyses show between 5.99 and 9.18 TiO_2.

Table XIV.—Commercial Analyses of Magnetites from the Gneisses and Pegmatites.—Continued.

Mine.	*Character of Sample.*	*Fe*	*P*	*S*	*Mn*	*Ti*		*P in 100 pts. Fe.*	*Authority.*
West End or Turkey Hill,	Shaft No. 1,	35.31	.006	.126	....	....	....	.017	10th Census, p. 162.
West End or Turkey Hill,	Shaft No. 3,	30.45	.000	.034	....	....	....	.000	10th Census, p. 162.
West End or Turkey Hill,	Shaft No. 4,	52.48	.004	.013	....	....	....	.008	10th Census, p. 162.
Wharton or Willis,	Shipment, 1880,	49.82	.343	....	....	....	....	.689	10th Census, p. 173.
Willis,	See Wharton.								
Wright or Budd,	Red ore,	49.88	.342	1.382	....	....	....	.685	10th Census, p. 158.
	Blue ore,	47.62	.521	2.824	....	....	....	1.094	10th Census, p. 158.

Partial Analyses—Among the partial analyses are included those that contain records of the determination of all the constituents that occur in noteworthy quantity and of those which, though in small quantity, affect the smelting quality of the ore. Except when otherwise indicated they are probably all trustworthy.

Table XV.—Partial Analyses of New Jersey Mixed Magnetite and Limonite Ores. (Ore Deposits in the Franklin Limestone.)

	1			2		3	4
	A	*B*	*C*	*A*	*B*		
SiO_2, ...	16.96	10.60	15.705	29.69	29.54	1.20	.60
Fe_3O_4, ...	....	70.24	65.801	47.95	48.23	93.27	
Fe_2O_3, ...	50.91	7.52					83.63
Al_2O_3, ...	4.06	1.85	1.347	6.41	5.84	.74	2.67
CaO, ...	.66	.29	1.260	9.14	10.09	.31	4.82
MgO, ...	1.54	.62	1.636	3.10	2.89	.51	1.22
MnO_2, ...	11.28	4.19	6.883	MnO = .45	MnO = .44	1.16	MnO = .65
P_2O_5, ...	.33	tr	.211	.018	.028	.046	.10
S, ...	.20*a*	.06*a*	.038	.584	.380	.08	1.09*a*
TiO_2, ...	tr	tr	....	.31	.21	tr	00
H_2O+, ...	7.16	2.55	undet.	....	....		CO_2=4.63
H_2O-, ...	5.13	1.36	undet.	....	....		C= .70
BaO, ...	1.44	.41	....	....	....	....	....
Total, ..	99.67	99.69		97.652*b*	97.648*b*	97.316*b*	100.11*c*

1—(*A*). Ahles Mine. Soft, brown ore, separated from crude ore which is a mixture of *A* and *B*. Analyst, E. C. Sullivan, U. S. G. S., 1905. The complete analysis of this ore is given on page 111.

(*B*). Ahles Mine. Hard, granular, black ore, separated from crude ore. Analyst, E. C. Sullivan, 1905. The complete analysis is given on page 111.

(*C*). Ahles Mine. Mixed ore, dried at 212°. N. J. 1904, p. 295.

2—(*A*). Bedell Mine (Redell Mine). Probably black ore, similar to 1 *B* from Ahles Mine. N. J. 1899, p. 166.

(*B*.) Bedell Mine (Redell Mine). Probably similar to 1 *B* from Ahles Mine. N. J. 1899, p. 166.

3— Little Mine. Black ore. Probably similar to 1 *B* from Ahles Mine. N. J. 1899, p. 169.

4— Howell Farm Mine. Average ore. N. J. 1873, p. 86.

(*a*). Reported as SO_3.

(*b*). *Note.*—This ore was probably dried at 212°. The differences between the summations and 100% is no doubt due to the omission of the determination of water.

(c). Total too large, since all iron is calculated as Fe_2O_3.

Table XVI.—Partial Analyses of New Jersey Magnetic Ores.
(Ore Deposits in Gneiss.)

	1	*2*	*3*	*4*	*5*	*6*	*7*
SiO_2, ...	2.475	2.11	17.46	11.90	9.95	49.40	11.70
Insol.	....	....	....	....	.50	5.00	....
Fe_2O_3, ...	....	....	....	....	....	....	77.42
Fe_3O_4, ...	90.110	91.50	69.24	79.40	84.59	37.265	....
Al_2O_3, ...	.920	1.13	1.70	....	2.68	4.764	2.04
CaO, ...	2.680	.89	7.20	2.70	....	tr.	3.19
MgO, ...	.480	.46	4.12	.94	....	1.611	2.58
MnO, ...	....	00	.26	—	....	.40	....
P_2O_5, ...	1.380	.212	.575	.092	.025	.096	3.10
S, ...	FeS_2 =	.63	.234	.59	.05	....	tr
TiO_2, ...	.300	....	....	tr	....	....	.75
CO_2, ...	.680	....	....	....	....	....	....
H_2O, ...	....	....	....	....	....	1.200	....
Total, ...	99.025	96.93	100.789	95.622	97.795	99.736	100.78*a*

1—Baker (Mine Hill) Mine.
2—Bishop Mine (re-opened Jackson Mine). Shipment analyzed at Secaucus Furnace, 1907.
3—Car Wheel Mine (Stockpile). Empire Steel and Iron Co. Geo. F. Corwin, Anal.
4—Fisher (Fox Hills) Mine. N. J. 1877, pp. 49–50.
5—Gray Mine.
6—Henry Tunnel Mine. N. J. 1873, p. 79.
7—Huff Mine. N. J. 1880, p. 106.

	8	*9*	*10*		*11*	*12*
			a	*b*		
SiO_2, ...	18.90	16.15	7.90	3.81	9.80	21.80
Insol., ...	....	....	....	....	....	....
Fe_2O_3, ...	....	....	....	....	73.15	....
Fe_3O_4, ...	65.52	68.48	85.88	92.01	....	58.29*d*
Al_2O_3, ...	12.48	3.34	2.14	1.00	9.48	9.00
CaO, ...	4.45	4.87	....	....	1.46	4.37
MgO, ...	.86	1.94	.36	.25	.72	4.03
MnO, ...	.55	....	Mn_3O_4 = .21	= .23	....	.50
P_2O_5, ...	.06	3.01	.48	.44	.54	.32
S, ...	1.23	....	.06	.02	.06	.05
TiO_2, ...	1.30	1.09	....	....	4.40	tr
CO_2, ...	....	....	$CaCO_3$ = 2.95	= 2.19	....	....
H_2O, ...	....	.40	....	....	....	1.64
Total, ...	105.35*b*	99.28	99.98	99.95	99.61*a*	100.00

8—Hoit Farm Mine. N. J. 1873, p. 80.
9—Horton Mine. N. J. 1873, p. 40.
10—Hurdtown Mine. N. J. 1885, p. 105.
11—Jackson Mine. N. J. 1873, p. 27 (see, also, No. 2).
12—Kishpaugh Mine. N. J. 1873, p. 83.

	13	14	15	16	17	18	19	20 a	20 b
SiO_2, ...	....	14.84	....	7.32	18.30	14.87	6.70	17.77	17.21
Insol., ...	28.50	....	2.40	....	....	....	....	....	....
Fe_2O_3, ...	....	....	.....	95.08	....	....	....	....	....
Fe_3O_4, ...	64.36	70.78	82.78	....	67.471	75.08	83.04	69.25	71.81
Al_2O_3, ...	3.50	2.04	*e*	....	3.226	.40	3.87	4.48	4.02
CaO, ...	.45	7.54	2.70	.31	5.936	2.32	3.25	3.40	2.22
MgO, ...	1.76	2.98	.91	....	3.276	5.31	.86	1.98	2.34
MnO,. ...	.30	.22	....	.30	.250	.23	Mn_3O_4 =	.26	= .18
P_2O_5, ...	.069	.64	2.56	.03	tr	.046	1.92	1.62	1.06
S, ...	.22	.15	.041	.10	....	....	.10	.102	.01
TiO_2, ...	tr	.59	6.40	....	....	....	.70	....	....
CO_2, ...	....	....	....	....	....	....	....	....	....
H_2O, ...	....	....	....	....	1.950	....	....	....	....
NiO, ...	....	....	....	....	....	.63	....	....	....
Total, ...	99.159	99.84	97.791*c*	103.14*a*	100.409	98.886	100.44	98.862	98.85

13—McKean Mine. N. J. 1874, p. 28.
14—McKinley Mine. N. J. 1903, p. 100.
15—Naughright Mine. N. J. 1878, p. 100.
16—New Mine. N. J. 1873, p. 61.
17—Pequest Mine. N. J. 1873, p. 78.
18—Petty Mine. N. J. 1899, p. 166.
19—Stoutenburgh Mine. N. J. 1873, p. 58.
20—Teabo Mine. N. J. 1885, p. 102.

	21	22	23	24	25	26	27	28
SiO_2, ...	10.18	5.40	....	....	....	....	....	....
Insol., ...	....	....	18.10	7.00	3.10	5.80	2.00	4.60
Fe_2O_3, ...	....	....	65.95*f*	76.00*f*	96.16*f*	90.47*f*	94.66*f*	84.56*f*
Fe_3O_4, ...	82.22	69.34	(63.97)	(73.80)	(93.28)	(87.76)	(91.82)	(82.02)
Al_2O_3, ...	1.90	9.29	5.09	1.94	1.74	1.91	.39	3.00
CaO, ...	2.86	.39	6.83	7.77	....	....	2.58	5.04
MgO, ...	.85	3.35	.07	.14	.22	.72	.21	tr
MnO, ...	.14	00	....	....	....	....	.20	.25
P_2O_5, ...	.98	tr	5.56	6.59	tr	tr	2.50	4.74
S, ...	.375	1.21	....	....	....	....	....	....
TiO_2, ...	.17	11.60	.80	.70	.70	2.72	.65	.50
Total, ...	99.675	100.58	102.40	100.22	101.92	101.62	103.19	102.69
			(100.42)	(97.94)	(99.04)	(98.91)	(100.35)	(100.15)

21—Washington Mine (roasted ore). N. J. 1903, p. 99.
22—Van Syckles Mine. N. J. 1873, pp. 55–56.
23–37—Ore of Ringwood Mines. N. J. 1873, pp. 53–54.
23—Cannon Mine, No. 1 ore. N. J. 1873, pp. 53–54.
24—Cannon Mine, No. 2 ore. N. J. 1873, pp. 53–54.
25—Cannon Mine, No. 3 ore. N. J. 1873, pp. 53–54.
26—Cannon Mine, No. 4 ore. N. J. 1873, pp. 53–54.
27—St. George Mine. N. J. 1873, pp. 53–54.
28—Miller Mine. N. J. 1873, pp. 53–54.

	29	30	31	32
SiO_2,	....	....	....	....
Insol.,	4.10	5.60	12.60	3.10
Fe_2O_3,	95.98*f*	90.14*f*	78.30*f*	85.08*f*
Fe_3O_4,	(93.10)	(87.44)	(75.95)	(82.53)
Al_2O_3,	.66	1.00	1.17	2.80
CaO,	....	2.13	4.03	6.62
MgO,	.43	.94	tr	.28
MnO,	....	.30	.25	.20
P_2O_5,	.06	1.86	3.39	5.12
S,	....	.01	.01	tr
TiO_2,	1.95	.40	1.44	tr
Total,	103.18	102.38	101.19	103.20
	(100.30)	(99.68)	(98.84)	(100.65)

29—**Old Blue Mine.** N. J. 1873, pp. 53–54.
30—**Hard Mine.** N. J. 1873, pp. 53–54.
31—**Keeler Mine.** N. J. 1873, pp. 53–54.
32—**Cooper Mine.** N. J. 1873, pp. 53–54.

	33	34	35	36	37
SiO_2,	....	....	....	....	....
Insol.,	5.40	3.00	2.60	17.30	28.90
Fe_2O_3,	91.11*f*	94.06*f*	97.29*f*	69.64*f*	70.68*f*
Fe_3O_4,	(88.38)	(91.24)	(94.37)	(67.55)	(68.56)
Al_2O_3,	3.19	2.59	.52	9.17	.72
CaO,	1.23	1.57	.62	....	tr
MgO,	tr	.22	tr	tr	.47
MnO,	.20	.25	.35	.15	00
P_2O_5,	.90	.45	.47	.19	.13
S,	....	....	tr	4.54	.20
TiO_2,	.30	.30	.52	....	....
Total,	102.33	102.44	102.37	100.99	101.10
	(99.60)	(99.62)	(99.45)	(98.90)	(98.98)

33—**Peters Mine.** N. J. 1873, pp. 53–54.
34—**Old Hope Mine** N. J. 1873, pp. 53–54.
35—**New Hope Mine.** N. J. 1873, pp. 53–54.
36—**Hewitt Mine.** N. J. 1873, pp. 53–54. (In New York, just across the State line.)
37—**Snyder Mine.** N. J. 1873, pp. 53–54. (In New York, just across the State line.)

REMARKS.

a—**Totals too large in consequence of calculation of all iron as** Fe_2O_3. **In No.** 7 **the corresponding** Fe_3O_4=75.09% **and the total is** 98.45: **In No.** 11 **the corresponding figures are** 70.96%, **and** 97.42, **and in No.** 16, 92.23% **and** 100.29.

b—**Total given in original as** 100.25. **The difference between the two footings is slightly reduced by the excess of oxygen reported by the analyst. The metallic iron equivalent of the iron-oxides found is given as** 61.69. **It should be** 47.44. **The analysis is plainly untrustworthy.**

c—**Contains grains of apatite.**

d—**Since total metallic iron is given as** 54.25 **there is evidently something wrong in the record of the analysis.**

e—Alumina (Al_2O_3) included with insoluble material.

f—In all analyses of the ores of the Ringwood group of mines the iron is calculated as Fe_2O_3 and consequently the totals are correspondingly too large. Upon the assumption that it is all in the form of magnetite (Fe_3O_4) the totals should be as indicated by the figures in parentheses.

Note.—Nos. 3, 14 and 16 are analyses of ore from practically the same mine.

While the analyses quoted above are not all of equal value and several exhibit unquestionable evidence of inaccuracy, they nevertheless represent in a fair way the general character of the magnetic ores of the State, as prepared for market. Of course, it is understood that by more careful cobbing the iron contents of some of the ores might be increased to a considerable extent and the other components diminished. It is, however, not certain that the consequent increase in the market value of the resulting product would be sufficient to pay the cost of its more careful treatment. Some of the ores might be concentrated with benefit by magnetic separators, but on the whole it is probable that under the present condition of the market such concentration would not prove profitable.

An inspection of the analyses reveals at once the reason why the New Jersey ores may compete with the richer ores of the Lake Superior region. The impurities are mainly silica, alumina, lime and magnesia. The silica is usually low and there is commonly a fair quantity of magnesia and lime present. The ores, though more difficult to work than many of the Lake Superior hematites, serve as excellent mixers with these.

A comparison of the analyses of the ores associated with the gneisses and those of the ores in limestone brings out several facts of interest. While the ores from the deposits in limestone, as prepared for the market, are usually lower in iron than the ores in the gneisses, they contain larger proportions of manganese and much smaller proportions of sulphur and phosphorus. Further, their titanium content is much lower, while their water content, on the other hand, is higher. The same facts are brought out also by inspection of the commercial analyses listed on pages 93–105, viz.: the limestone ores are usually high in manganese and low in titanium and phosphorus, and the gneiss ores are low in manganese and comparatively high in the other two constituents.

Complete Analyses.—Complete analyses include determinations of all the components of an ore, whether they occur in large or in small quantity, or only in traces, and whether of importance to furnace men or not. Very few such analyses have been published heretofore. These are reprinted below, together with 12 new ones, made by Mr. R. B. Gage, of the State Geological Survey.

Table XVII.—Complete Analyses of New Jersey Iron Ores.

(Mainly magnetites in Franklin limestone.)

	1	2	3	4
SiO_2,	1.67	21.86	10.60	16.96
Al_2O_3,	.28	3.97	1.85	4.06
Fe_2O_3,	30.69	32.56	7.52	50.91
FeO,	14.43	15.42	Fe_3O_4=70.24	.....
MgO,	7.53	.16	.62	1.54
CaO,	17.63	18.57	.29	.66
Na_2O,	.....	.....	} .12	.08
K_2O,	.....	.05		.29
H_2O-,	.06	.12	1.36	5.13
H_2O+,	.18	.33	2.55	7.16
TiO_2,	.....	.13	tr	tr
CO_2,	22.25	1.58	.....	.....
P_2O_5,	.077	.051	tr	.33
FeS_2,	.780	4.530	.....	.....
$FeAs_2$.	.47	.....	.....	.....
NiS,	.....	.01	.....	.....
MnO,	2.90	.32	MnO_2= 4.19	=11.28
CoS,	.....	.01	.....	.....
CuS,	.03	.12	.....	.....
ZnS,	.....	.24	.....	.....
PbO,	.....	tr	BaO= .41	= 1.44
Sb_2S_3,	.05	.....	SO_3= .06	= .20
C (graphite),	.98	.....	.....	.....
Total,	100.007	100.031	99.81	100.04

Insoluble.	*2.41*	*23.67*
SiO_2,	1.67	21.86
Al_2O_3,	.45	1.08
MgO,	.08	.16
CaO,	.19	.51
K_2O,	....	.05
Total,	2.39	23.66

1—Ore of Pikes Peak Mine at Franklin Furnace. Sample taken from pile of 150 tons at furnace. Report of 10th Census, p. 154.

2—Cobbed ore. Sulphur Hill Mine. Sample from pile of 80 tons on mine dock. Report of 10th Census, p. 153.

Ore consists of mixture of magnetite, garnet, pyrite, pyrrhotite, and a little hornblende. There are also closely associated with the ore calcite and various zinc minerals, fluorspar, galena and copper compounds. The ore is unique among the New Jersey magnetites. It resembles, in some respects, the ores of the "zinc vein" at Franklin Furnace.

3—Magnetite separated from ore of Ahles Mine. Analyst: Eugene C. Sullivan, U. S. Geol. Survey.

4—Limonite separated from ore of Ahles Mine. Analyst: Eugene C. Sullivan, U. S. Geol. Survey.

The ore of the Ahles Mine is a mixture of limonite and magnetite, the latter often exhibiting crystal boundaries. A sample of the crude ore was taken from the stock pile and separated into three portions with the aid of a magnet and by washing. Of these, one containing 63% of the entire mixture, was hard, granular and magnetic (*3*). Another, comprising 15% of the crude material, was soft, ocherous and non-magnetic (*4*). The remaining 22% was a mixture of these.

Table XVIII.—Complete Analyses of New Jersey Magnetites.
(Ore in Gneiss.)

	1	*2*	*3*	*4*
SiO_2,	7.63	4.06	9.25	26.83
Al_2O_3,	3.08	1.73	1.98	2.71
Fe_2O_3,	56.37	61.13	55.71	34.26
FeO,	25.34	29.73	26.64	18.98
MgO,	.27	.43	1.11	5.82
CaO,	4.09	1.29	1.89	5.87
Na_2O,	....	.09	.57	1.21
K_2O,	....	.03	.12	.69
H_2O+,	.38	.24	.56	1.02
H_2O-,	....	.05	.43	.66
TiO_2,	.09	.14	.54	1.24
ZrO_2,	....	....	.00	....
CO_2,	.06	.26	.35	.95
P_2O_5,	2.444	.389	.86	.07
S,	....	....	.07	....
FeS_2,	.212	.144	....	....
Cr_2O_3,	....	....	.01	....
NiO,	....	....	.02	....
MnO,	.34	tr	.05	.14
CoO,	....	....	.00	....
CuO,	....	....	.00	....
ZnO,	....	....	.00	....
BaO,	....	....	.00	....
SrO.	....	....	.00	....
Li_2O,	....	....	.00	....
V_2O_3,	....	....	.14	....
C in carbonaceous matter,	....	.03	....	....
Total,	100.306	99.793	100.30	100.45

Insoluble.	9.69	5.36		
SiO_2,	7.63	4.05	....	....
Al_2O_3,	1.99	.17	....	....
FeO,	....	.58	....	....
MgO,	.02	.17	....	....
CaO,	.04	.27	....	....
Na_2O,	....	.09	....	....
K_2O,	....	.03	....	....
	9.68	5.37		

1—Ore of the Pardee Mine of the Ogden Mine group. Sample from stock pile of 2,500 tons. Report of 10th Census, p. 155.
2—Ore of the Hurdtown Mine. Sample taken from 17 carloads ready for shipment. Report of 10th Census, p. 157.
3—Cobbed ore. Hibernia Mine. Representing shipments of 1906. Analyst: W. T. Schaller, U. S. Geol. Survey.
4—Lean ore. Richard Mine. Single sample. Analyst: W. T. Schaller, U. S. Geol. Survey.
5—Richard Mine. North, or Mt. Pleasant Vein. Selected sample, 1908. Analyst: R. B. Gage.

	5	6	7	8	9	10
SiO_2,	1.31	2.22	3.77	8.48	12.08	7.14
Al_2O_3,	.73	.59	.79	.86	1.63	1.23
Fe_2O_3,	64.01	62.76	61.16	55.99	56.21	60.89
FeO,	30.62	28.59	29.56	26.98	26.39	25.94
MgO,	.33	.74	.64	1.89	.88	1.40
CaO,	.96	2.54	1.23	2.42	1.08	1.31
Na_2O,	tr	tr	.12	.33	.17	.08
K_2O,	tr	tr	.14	.19	.15	.13
H_2O+, H_2O-,	.10	.13	.16	.15	.17	.25
TiO_2,	1.29	.30	1.30	1.01	1.21	1.25
P_2O_5,	.563	1.89	.448	1.54	.023	.529
S,	.12	.14	.011	.008	.026	.014
Cr_2O_3,	.00	.00	.00	.00	Some	.00
NiO,	.00	.00	.00	.00	.00	.00
MnO,	.05	.04	.06	.02	.07	.03
CoO,	.00	.00	.00	.00	.00	.00
BaO,	.00	.00	.00	.00	.00	.00
SrO,	.00	.00	.00	.00	.00	.00
V_2O_3,	.10	.11	.095	.08	.21	.15
Total,	100.183	100.65	99.484	99.948	100.299	100.343

6—Richard Mine. South Vein. Selected sample, 1908. Analyst: R. B. Gage.
7—Richard Mine. Ore of North, or Mt. Pleasant vein. Average sample, 1908. Analyst: R. B. Gage.
8—Richard Mine. South vein. Average sample. Represents shipping ore, 1908. Analyst: R. B. Gage.
9—Hibernia Mine. Selected sample, 1908. Analyst: R. B. Gage.
10—Hibernia Mine. Average sample, 1908. Analyst: R. B. Gage.

	11	12	13	14	15	16
SiO_2,	3.56	7.62	1.38	8.46	1.51	6.37
Al_2O_3,	.44	.49	.55	.77	.37	1.59
Fe_2O_3,	61.47	55.24	65.26	56.18	64.87	57.46
FeO,	29.04	26.12	30.20	27.81	31.11	27.23
MgO,	1.68	1.89	.10	1.88	.40	1.01
CaO,	1.66	4.34	.68	1.68	.51	2.93
Na_2O,	.10	.27	tr	.22	tr	.12
K_2O,	.12	.20	tr	.36	tr	.18
H_2O+, H_2O-,	.16	.21	.12	.28	.09	.21
TiO_2,	1.15	1.05	1.09	1.06	1.05	.70
P_2O_5.	.541	2.44	.49	.98	.053	2.18
S,	.021	.02	.01	.01	.007	.046
Cr_2O_3,	.00	.00	.....	.00	.00	.00
NiO,	.00	.00	.00	.00	.00	.00
MnO,	.03	.04	.03	.04	.08	.03
CoO,	.00	.00	.00	.00	.00	.00
BaO,	.00	.00	.00	.00	.00	.00
SrO,	.00	.00	.00	.00	.00	.00
V_2O_3,	.08	.08	.08	.11	.13	.08
Total,	100.052	100.01	99.99	99.84	100.33	100.136

11—Leonard Mine, Mt. Hope. Selected sample, 1908. Analyst: R. B. Gage.
12—Leonard Mine, Mt. Hope. Average sample, 1908. Analyst: R. B. Gage.
13—Elizabeth Mine, Mt. Hope. Selected sample, 1908. Analyst: R. B. Gage.
14—Elizabeth Mine, Mt. Hope. Average sample 1908. Analyst: R. B. Gage.
15—Hurd Mine, Wharton. Selected sample, 1908. Analyst: R. B. Gage.
16—Hurd Mine, Wharton. Average sample, 1908. Analyst: R. B. Gage. Contains also a little chlorine.

The complete analyses of the New Jersey magnetites confirm the conclusions reached in the discussion of the numerous commercial and partial analyses. The ores in the limestone are characterized by the presence of a less quantity of titanium and phosphorus than the ores in the gneisses and a greater quantity of manganese, though possibly exceptions to this generalization are occasionally met with. The ores in the gneiss are as a rule more uniform in character than the limestone ores, though both contain a large number of ingredients. The greater variety of substances present in the limestone ores is due largely to the fact that the limestone itself, being highly metamorphosed in places, contains many different constituents and the rock is not as completely separated in mining as is the case with the gneiss ores.

MINERAL COMPOSITION.

Mineralogically the magnetite ores of New Jersey consist of the mineral magnetite, associated with the usual components of the rocks in which the ore bodies occur. In the case of the ores occurring in the gneisses the principal components in addition to the magnetite are hornblende, pyroxene, feldspar, quartz, apatite, sphene and pyrrhotite and pyrite.

The titanium is evidently present in two forms, viz., as the mineral sphene, which can often be detected in thin sections cut from the ores, and also partly replacing iron in the magnetite. Its condition in the latter form is indicated by analyses Nos. 4, 13 and 15, which were made on samples selected for their apparent purity. If the phosphorus shown in these analyses is in the form of apatite then there is not enough calcium present in any of the samples to combine with all the titanium to form sphene. The excess of titanium is either in the form of ilmenite or is in the magnetite. On the assumption that all the phosphorus is in apatite, that the excess of calcium above that in the apatite is combined with titanium in sphene, and that the balance of this element is in ilmenite, the analyses Nos. 4, 13 and 15 contain these minerals in the following proportions:

	4	*13*	*15*
Magnetite,	93.03	94.77	94.19
Apatite,	1.34	1.18	.13
Sphene,	.78	.....	1.57
Ilmenite,	1.82	1.82	.76
Others,.	3.36	2.27	3.60
	100.33	100.04	100.25

The constitutents of the magnetically cobbed Hibernia ore as calculated from its analysis (*3*), is approximately as follows:

Magnetite,	79.60
Hornblende, Pyroxene.	6.25
Oligoclase,	6.40
Orthoclase,	.72
Quartz,	2.07
Apatite,	2.01
Sphene,	1.35
Pyrite,	.01
Calcite,	1.59
	100.00

The ores from other mines in the gneiss vary from this mainly in the proportion of the different minerals, and this in turn depends largely upon the carefulness of cobbing. Between magnetite-bearing gneiss and high grade ore-bodies there are all gradations into country rock containing little magnetite.

In rare cases the proportion of apatite in the ores is so large that they are useless as sources of iron, but their phosphorus content is thereby so increased that attempts have been made to use them as raw material from which to manufacture fertilizer.

In addition to the minerals mentioned above as present in most of the ores there are present in some of them also biotite, chlorite, garnet, epidote, sillimanite, fluorite, molybdenite, molybdite (MoO_3), gummite (uranium compound) and some substance containing vanadium, which, as will be noticed by reference to the analyses (pages 111–114), has been detected in almost all the specimens analyzed.

Most of the ores associated with the limestones are not much different from those in the gneisses. The composition of the insoluble constitutents shows these to consist of quartz and hornblende or pyroxene, and in the case of the Sulphur Hill Mine, also willemite. The soluble components are magnetite, calcite, pyrite, pyrrhotite, and other sulphides, among them chalcopyrite, galena and sphalerite, and also sphene and apatite. In the case of the Ahles ore there is in addition a large quantity of pyrolusite present in little nodules scattered through the limonite, but this is rather unusual. The magnetite is non-titaniferous (see analysis 3, p. 111), and thus appears to differ from that in the ores associated with the gneisses. In the limestone ores there is also often present considerable garnet, and in some instances some chondrodite and serpentine—these three minerals being common constituents of the metamorphosed limestone with which the ore bodies are associated.

Palache[1] mentions also as present in the magnetite near Franklin Furnace the minerals allanite, arsenopyrite, phlogopite, rutile, scapolite, iron spinel and zircon, and states that some of them are directly traceable to the granite associated with the ores, but he does not specify which these are. Most of the minerals named are probably in the ore within limestone.

[1] Folio 161 U. S. Geol. Survey, p. 8–10, and Folio No. 2 Geol. Atlas of N. J., p. 8–10.

CHAPTER VI.

GEOLOGY OF THE MAGNETITE-BEARING ROCKS.

CONTENTS.

The magnetic ores of New Jersey, as has been stated, occur in the pre-Cambrian rocks of the State. Unlike the hematites, however, they are associated either with the white limestone of the Franklin formation or with the gneisses. So intimate is this association that a knowledge of the character and manner of occurrence of these rocks is necessary before the relationships of the ore to the country rocks can be appreciated.

It has already been remarked that the pre-Cambrian rocks of New Jersey are practically confined to the Highland area, and that they comprise various gneisses, pegmatites and a series of sedimentary rocks that have been grouped together under the name of the Franklin formation, of which the most important member is a white crystalline limestone. These rocks form a series of northeast-trending ridges separated from one another by

intervening valleys of Paleozoic quartzites, limestones and slates. The ridges are composed mainly of gneisses. In the valley of the Wallkill River near Franklin Furnace, at Marble Mountain and between Pequest and Oxford Church there are considerable areas of Franklin limestone; but in most instances the limestone occurs in very small detached masses entirely surrounded by gneiss.

The rocks are distributed in belts striking in general parallel to the trend of the ridges, *i. e.,* to the northeast, and dipping southeast. Here and there, however, they strike and dip in other directions over comparatively small areas and in a few places they are curved. In the gneisses the belts consist of the outcropping edges of layers of different composition that wedge out at their ends, and thus exhibit on the surface the outlines of sections of flat lenses. Since the gneisses are by far the most prominent rocks of the Highlands this arrangement of the rocks constituting the ridges may be said to be characteristic.

THE FRANKLIN FORMATION.

The oldest rocks of the region comprise a series of sediments that are included under the name of the Franklin formation, because of the preponderance in it of the well-known white or gray crystalline limestone so well exposed near Franklin Furnace. The formation embraces, in addition to the limestone, a few conglomerates, quartzites, and slates.

The fragmental rocks are not widely spread. They occur principally at Andover, near McAfee, and at Marble Mountain. The conglomerates and quartzites are massive dark-red varieties, the former containing in most cases numerous pebbles of white quartz, and having associated with them in a few places a greater or less quantity of hematite.

The slates are rare, and differ greatly in appearance at different places. At Marble Mountain they are purple or yellow talcose rocks that apparently grade into quartzites. At Andover they are dark red and siliceous, like shaly quartzites. At Pottersville Falls gray, banded and schistose rocks occur that resemble strongly sheared rhyolites or other acid lavas or tuffs. Finally, at the north end of Cranberry Lake there is a large inclusion of a dark-gray slaty rock embedded in the gneiss.

The limestone is usually a white crystalline marble which varies greatly in texture from place to place. It is generally coarsely granular, but in some places it is fine grained, and in a few localities is nearly amorphous. This passes locally into pink or yellow or gray varieties, and at one place, near Danville, it is a mottled red and white rock speckled with black flakes of biotite. At many places the limestone is free from included minerals, but usually it contains diopside, tremolite, chondrodite, phlogopite, and quartz and often small flakes of graphite. Magnetite, sphalerite and garnet occur locally. Serpentine is abundant at many places as an alteration product of the diopside and chondrodite, and talc and asbestos have been observed in a few places where the rock has been sheared. Where the number of the included minerals is large the rock loses its white color and becomes dark gray or green. Bedding is obscure. When observable, however, it usually strikes and dips conformably with the gneisses. In a few places it is apparently folded, but cases where folding has been proven are extremely rare. The small areas of the rock scattered through the Highlands are small plates completely embedded in gneiss.

The limestone is cut by dikes of pegmatite and of basic rocks, most of which are identical in character with some of the black gneisses forming integral portions of the gneiss series. Some of these dark intrusions have apparently been affected by the limestone into which they have been forced, for their feldspars have been so completely replaced by scapolite that the rocks have now the mineralogical composition of scapolite gabbros or scapolite diorites. Other dark dike rocks that intrude the Franklin limestone in the neighborhood of Franklin Furnace are tinguaites and camptonites that are connected with the nepheline syenite intrusion near Beemerville in Wantage Township, in Sussex County. In a few places tongues of the lighter gneisses also penetrate the limestone.

From the relation of the limestone to the gneisses it is inferred that the limestone is the older and that, together with the quartzites, conglomerates and slates it represents an old series of rocks into which the gneisses and the pegmatites were forced.

THE PROMINENT GNEISSES.

The gneisses consist of alternations of approximately parallel layers rich in potash with others rich in soda and others rich in magnesia and iron. The rock rich in potash is designated the Byram gneiss, the soda-rich forms are called the Losee gneiss and the magnesia-iron varieties the Pochuck gneiss. All varieties exhibit a more or less well-defined linear structure in the arrangement of their constituents which are elongated into cylindrical grains, or are grouped in little cylindrical aggregations. This structure dips and strikes in the same direction as the gneiss layers and usually pitches northeasterly at comparatively low angles (15°-40°). The strike of the layers is usually northeasterly and their dips high to the southeast, though strikes and dips in other directions are sometimes met with. In a few places, where the layers curve, the dips change correspondingly.

There is no evidence of any kind that the gneisses are metamorphosed sediments. They are completely crystallized and exhibit no structures such as are associated with rocks of sedimentary origin. In earlier descriptions of the Highlands it was stated that the more massive phases of the gneisses occur in the axes of the ridges and their more schistose varieties on the flanks. Later studies show this generalization to be an error. Massive and schistose phases are not distributed in any such symmetrical manner. The two phases grade into one another and either may be found on the tops or along the sides of the ridges.

The Losee Gneiss.—In its best characterized phase the Losee gneiss is a white rock composed of oligoclase and quartz with minor amounts of a light-green diopside, sphene, apatite, and magnetite, and in some specimens a little biotite. Hypersthene is present to a considerable extent in some varieties, when the rock takes on a greenish tinge. The linear structure is not as pronounced in the Losee gneiss as it is in the Byram gneiss because of the lack of contrast in the color of its components. On fractures across the structure the rock is typically granular, but in other directions a more or less well-defined schistosity is noticed, especially in the shape and arrangement of the quartz.

An analysis of a pure white variety nearly free from diopside and hypersthene gave the following percentage composition:

Analysis of Losee Gneiss from knob near Berkshire Valley.[1]

(W. T. Schaller, Analyst.)

SiO_2,	77.53
Al_2O_3,	13.60
Fe_2O_3,	.23
FeO,	.16
MgO,	Trace.
CaO,	.73
Na_2O,	6.65
K_2O,	1.20
H_2O-,	.15
H_2O+,	.18
TiO_2,	.16
CO_2,	Trace.
P_2O_5,	.03
MnO,	Trace.
	100.62

Norm, or Standard Mineral Composition, of Losee Gneiss, calculated from Chemical Analysis.

Quartz,	32.85
Orthoclase,	7.23
Oligoclase (albite, 56.07; anorthite, 3.43),	59.50
Other components,	1.22
	100.80

The Byram Gneiss.—The Byram gneiss is a medium to coarse-grained gray rock in its most characteristic outcrops. Its essential components are microcline, a microperthite, orthoclase, quartz, brown and green hornblende, and sometimes green pyroxene. The accessories are sphene, apatite, and magnetite, and sometimes biotite. In some varieties quartz predominates over the feldspars. In some it approximately equals them. In others the feldspars are in excess. A very light-gray variety containing very few dark components yielded upon analysis by Dr. W. T. Schaller the following result:

[1] Folio No. 157, U. S. Geological Survey, p. 5. Folio No. 1, Geol. Atlas of N. J., p. 5.

Analysis of Byram Gneiss from Quarry One Mile West of Hibernia.[1]

(W. T. Schaller, Analyst.)

SiO_2,	77.07
Al_2O_3,	12.61
Fe_2O_3,	.71
FeO,	.73
MgO,	Trace.
CaO,	.87
Na_2O,	3.43
K_2O,	4.06
H_2O-,	.23
H_2O+,	.62
TiO_2,	.12
CO_2,	Trace.
P_2O_5,	Trace?
MnO,	.09
	100.54

Norm, or Standard Mineral Composition, of Byram Gneiss, calculated from Chemical Analysis.

Quartz,	39.13
Orthoclase,	24.46
Plagioclase (albite, 28.82; anorthite, 4.37),	33.19
Other constituents,	3.13
	99.91

The structure of the Byram gneisses is usually strongly linear, but in some outcrops the rock is completely massive. On the surfaces of all fractures that are perpendicular to the direction of elongation of the component minerals the texture is as granular as that of any granite.

The Pochuck Gneisses.—The black gneisses are all grouped together under the name of Pochuck gneiss. It is possible that the group is complex; *i.e.*, that all the rocks placed in it are not of the same origin. It may well be that some of the dark gneisses, like some of those in the Adirondacks and others in Eastern Ontario, are metamorphosed sediments or tuffs. Many of them are certainly igneous in origin. These rocks consist essentially of brown hornblende, green augite and oligoclase,

[1] Ibid., p. 5.

with subordinate amounts of magnetite, apatite, and sphene and occasionally quartz. Where the Pochuck gneisses are closely associated with limestone, as in the tongues or dikes intruding this rock, the plagioclase is often completely replaced by scapolite. These are the rocks that have been so often described in the New Jersey reports as "Gefleckter gabbros." Mineralogically, the feldspathic phases may be regarded as augite diorites. Only one specimen has been analyzed. This is a sparkling black schist that might have been classed as a hornblende schist. Chemically it is almost identical with some of the norites described by Kemp as occurring in the Adirondacks.

The result of the analysis, which was made by Dr. W. T. Schaller, is given below.

Analyses of Pochuck Gneiss from the Pardee Magnetite Mine and of Norite from a Titaniferous Iron Mine near Lincoln Pond in the Adirondacks.

(W. T. Schaller, Analyst.)

	Gneiss.[1]	*Norite.*[2]
SiO_2,	43.98	44.77
Al_2O_3,	12.01	12.46
Fe_2O_3	6.60	4.63
FeO,	12.20	12.99
MgO,	5.46	5.34
CaO,	11.99	10.20
Na_2O,	2.93	2.47
K_2O,	1.10	.95
H_2O-,	.29	.12
H_2O+,	1.04	.48
TiO_2,	2.25	5.26
CO_2,	.18	.37
S,	....	.26
P_2O_5.	.28	.28
NiO,	....	Trace.
BaO,	....	Trace.
MnO,	.05	.17
	100.36	100.75

[1] Folio 157, U. S. Geol. Survey, p. 4. Folio No. 1, Geol. Atlas of N. J. p. 4.

[2] Kemp, J. F. 19th Ann. Report U. S. Geol. Survey. Pt. 3, 1899. p. 407.

The structure of the Pochuck gneisses is more schistose than that of either of the other gneisses. This is due mainly to the naturally elongated form of their principal constituents.

Distribution.—The separate phases of the gneisses are rarely found alone occupying any large areas, but each occurs intermingled with others in long narrow belts wedging out at their ends. Within these belts one type of gneiss may preponderate, but at the same time both the other phases are usually represented in smaller amounts. Not only is there often an interlamination of phases within a belt, but not infrequently one type may grade into another along the strike of the belts through intermediate phases. As a rule the Pochuck gneiss is more frequently associated with the Losee phase than with the Byram, though interbanding of the Pochuck and Byram phases is not unknown.

Relative Ages.—Because of the exceedingly intimate association of the different types of gneisses described above it is difficult to ascertain with certainty their relative ages. The Pochuck gneiss, or at any rate some forms of it, are unquestionably older than either the Byram or the Losee gneiss. The Byram and Losee gneisses are apparently approximately contemporaneous. Further than this it is hazardous to express an opinion.

OTHER GNEISSIC ROCKS.

Besides the gneisses that have been described there are present also in the gneiss complex long, thin layers of a garnetiferous graphitic gneiss, and of a graphite quartz schist. The former are fine to coarse grained aggregates of quartz, feldspar, biotite or muscovite, garnet, magnetite and graphite. They are strongly schistose and in many places they exhibit every evidence of having been crushed. The coarser varieties grade into garnetiferous pegmatites, though it is probable that some of them are crushed sedimentary rocks. The quartz-graphite schists are fine grained, very schistose, dark-gray, friable rocks composed of quartz, biotite, muscovite, occasionally a garnet, and a considerable quantity of graphite, in some cases reaching 3% to 4% of the rock's mass. The graphite is usually associated with

the biotite. The two are often intergrown, though in most cases they occur in plates lying side by side. Although no fragmental quartz grains can be discovered in the rock it is, nevertheless, thought that it was originally a sandstone, which has been recrystallized through the influence of igneous intrusions.

PEGMATITE.

The most prominent rock of the Highlands aside from the gneisses is pegmatite. It is the youngest of the pre-Cambrian rocks, since it is found cutting all the others. It occurs in irregular patches in the midst of the gneisses and grading into them, as dikes cutting across the structure of the district, but most frequently as sheets interpolated between the layers of the gneisses and the beds of the limestone.

Mineralogically the pegmatites are like the acid gneisses. Some of them contain oligoclase as their predominating feldspar, while in others the preponderating feldspars are microcline and microperthite. Their other components are hornblende, magnetite, graphite, and zircon, with occasionally a garnet. Hornblende is abundant in many instances, especially in pegmatites that are associated with magnetite ores. Magnetite and graphite are also often present in large quantity. The former mineral is so abundant in some places that the rock has been mined as an iron ore. Graphitic varieties are also occasionally found that are very rich in this constituent. In a few places these varieties have been mined as a source of plumbago.

The question as to the origin of the magnetite and graphite has not yet been completely solved. In some specimens these minerals are embedded in feldspar and hornblende and thus appear to be original. In other specimens, however, magnetite occurs in the interstices between the feldspars and the graphite, in plates wrapping around quartz grains. In these cases the two minerals appear to have been introduced subsequently to the solidification of the rock. This view if correct is important in its bearing upon the theory of the origin of the magnetic ores. (See pages 147 *et seq.*)

ORIGIN OF THE GNEISSIC COMPLEX.

Because of their similarity in composition to the acid gneisses it is inferred that the pegmatites are closely related in origin to the usual gneisses of the region. These rocks and the greater portion of the Pochuck gneisses are thought to have cooled from a molten magma which invaded a pre-existing series of sedimentary rocks of which the limestones, quartzites, conglomerates. and slates of the Franklin formation and probably the graphitic quartz-schists, and the finer grained garnet-graphite gneisses and possibly some of the Pochuck gneisses are the surviving remnants.

In most places the invasions were along lines running northeast and southwest, resulting in the regular banding which is so conspicuous a feature of the district. In certain places the first intrusions were along curved lines. Later ones followed these and there resulted the curved belts as seen south of Split Rock Pond. The linear structure of the gneisses is regarded as the direct result of the flowage of the viscous magma and of crystallization of some of the minerals of the rocks under the influence of the strains produced by the flowage. That it is not the result of mashing during the later stages of Paleozoic time when the folding of the Appalachian mountains was produced. is indicated by the fact that there is no evidence of crushing observed in any of the thin sections, made from specimens taken from points distant from faults. Moreover, the structure is found well developed in gneiss pebbles embedded in the Cambrian quartzites, and consequently was produced long before the Paleozoic rocks were folded. After the intrusion of the gneisses there was much addition made to the complex by the injection of fluid or thinly plastic material that afterwards solidified as pegmatite. This injection of material was for the greater part forced between the tabular massess or flat lenses of the already almost completely solidified rocks and spread out as plates between them forming the intercalated layers which now constitute the numerous pegmatitic bands that are so constant and uniform a feature of the gneiss areas. In a few cases the pegmatite ma-

terial cut across the foliation of the gneisses and formed veins or dikes.

DIKE ROCKS.

The youngest rocks of the region are certain dark basic intrusions that occur as small dikes cutting the gneisses and the members of the Franklin formation. Most of them are diabases that are offshoots of the great Newark trap masses to the south. Others are tinguates and camptonites that are probably apophyses of the nepheline syenite intrusion occurring between the Martinsburg shale and the Shawangunk conglomerates near Beemerville. The camptonite is represented by the great dike at the Buckwheat zinc mine at Franklin Furnace.

FAULTING.

Aside from the complexity caused by the interlaying of the various gneisses and their gradation into one another the structural features of the pre-Cambrian areas are comparatively simple. Great faults bound the Highlands on the south and separate the gneiss from the Paleozoic and Newark rocks. Others limit the southeast sides of the Highland ridges and form the northwest sides of the intervening valleys. The ridges together with the valleys on their northwest sides thus form parts of single crustal blocks, which were tilted northwestward and afterwards reduced to their present forms by erosion. Other great faults may have been produced within the gneiss areas parallel to the strike of the gneiss belts, but if so they have not yet been recognized.

Minor faults within the gneiss, however, are common, but all those that have thus far been discovered cut across the banded structure of the region. No longitudinal minor faults have been detected on the surface, although some of the phenomena observed in the mines indicate that a few may be present. The cross faults are easily recognized by the horizontal displacements they have produced in the banding of the gneisses and in the ore bodies in the mines. These displacements are nearly

always to the right as one faces the fault plane and are usually of small magnitude, although in a few instances they measure several hundred feet horizontally. The fault planes usually strike about N 30 W, and dip at high angles. These minor faults are of considerable practical importance, as they often seriously affect mining operations in the magnetite mines. (See also pages 140–144.)

COMPARISON OF THE NEW JERSEY HIGHLANDS GEOLOGY WITH THAT OF THE ADIRONDACKS AND EASTERN ONTARIO.

A comparison of the geology of the New Jersey Highlands with that of the Adirondacks and Eastern Ontario reveals the fact that the Franklin formation and the Byram, Losee, and Pochuck gneisses have their equivalents in the northern districts, and that in general the three districts are essentially similar.

The oldest rocks in the northern districts are crystalline limestones, quartzites, and micaceous schists that are considered to be metamorphosed sediments. Beneath these and also interlarded with them are augite gneisses that may be mashed intrusive granites or the extreme phases of metamorphism of arkoses or acid volcanic tuffs. This complex is invaded by gabbros and by rocks called syenites that are practically identical with the Byram gneiss in New Jersey.

In Ontario there is in addition a series of amphibolites which have a three-fold origin. Certain ones are considered to represent limestones that have been altered by invading granites. Others have been produced by the dynamic alteration of basic igneous intrusions; while still others have in all probability resulted from the recrystallization of basic, fragmental, volcanic material. All three processes have produced amphibolites that cannot be distinguished from one another either by appearance or by chemical composition. A gneissic granite intrudes the sedimentary rocks and contains fragments of the amphibolites. The geological conditions are thus practically the same in the Adirondack, Eastern Ontario, and the New Jersey Highlands, except that in the southern area no gabbros occur.

In the northern regions the fragmental rocks and the schists derived from them were collectively termed the Grenville series until very recently. The granite gneisses that are intrusive into them but which are structurally beneath them were called the Laurentian gneiss.

Messrs. Miller and Knight, however, have recently subdivided the Grenville series of Eastern Ontario into an older and a younger series which are described as being separated by an erosion unconformity. The younger series is correlated with the Huronian of the Lake Superior region and the older, for which the name Grenville is retained, is correlated with the sedimentary portion of the Keewatin series in the Lake region.

The igneous portion of the Keewatin is represented by a spheroidal or ellipsoidal greenstone in Ontario. No evidence of the existence of rocks referable to the igneous portion of the Keewatin has been discovered in New Jersey unless a few of the slates are of igneous origin, nor have any sediments been found that can be ascribed with certainty to the Grenville sediments of Miller and Knight.

It is not possible at the present time to fix the age of the New Jersey rocks with any great degree of accuracy. They are equivalent to the Grenville series as this term was employed before Miller and Knight redefined it, but whether they should be correlated with the Grenville or the Huronian series of these authors is not yet known.

[1] 16th Report Bureau of Mines, 1907. Printed by order of the Legislative Assembly of Ontario. pp. 222-223.

CHAPTER VII.

THE MAGNETITE ORE BODIES.

CONTENTS.

GENERAL CHARACTER.

Although magnetite occurs as an essential constituent of most of the siliceous rocks of the Highlands, at only a comparatively few places is it in sufficient quantity to be of economic importance. At these places it is probable that much of the ore material has been introduced since the various rocks attained their present position.

The principal magnetite deposits occur

(1) as small segregations in the gneisses,
(2) as richly magnetiferous pegmatites,
(3) as bands in the Franklin limestone,
(4) as interleaved layers in the gneisses.

Of these the deposits that occur interlaminated with the gneisses are of greatest importance since it is in these that most of the profitable mines in New Jersey occur.

Ore Segregations.—The segregations of ore are little bunches of nearly pure magnetite that occur here and there in the midst of the gneisses and grading into them in all directions. They

are considered to be basic secretions similar in mode of origin to the well-known secretions of titaniferous magnetite in many gabbros. In other words, they are thought to represent the oldest separations from the magmas which upon cooling gave rise to the gneisses. These are found principally in the Pochuck gneisses, but occur also in a few places in the Losee gneisses. They are so small that they have no economic value.

Magnetiferous Pegmatites.—It has already been stated that some of the pegmatites are so rich in magnetite that they have been mined as ore. In composition the magnetiferous pegmatites do not differ from other varieties of the rock except that they rarely contain graphite. They occur usually as layers interleaved with the gneisses, but in few instances they cut across the gneiss layers for short distances. Where the gneisses strike and dip uniformly the ore-bearing pegmatites do the same. Where the gneiss layers curve, so also do the pegmatites. In nearly all cases the pegmatites conform with the gneisses in these respects. In the few cases where the magnetite-bearing pegmatites occur in the Franklin limestone the pegmatite strikes northeast and dips southeast, in conformity with the gneisses surrounding the limestone areas.

The pegmatite is always a coarse-grained rock that contains an abundance of hornblende, quartz and feldspar. The magnetite is disseminated through it irregularly as inclusions within the other minerals and as irregular masses between them. The rock is therefore very unequal in quality as an ore. In some places it may be rich enough in iron to warrant working, but at short distances from these places it is apt to be quite lean. Moreover, because of its granitic character and the consequent necessity of breaking it into small pieces it is expensive to cobb. For these reasons it is not a satisfactory ore to work and consequently all the mines that were situated on pegmatite deposits have been abandoned with no hope of being reopened until the price of ore becomes much higher than it is at present.

Among the prominent mines that formerly utilized magnetiferous pegmatites as ore may be mentioned the Beach Glen and some of the Ogden mines.

Ore Bodies in the Franklin Limestone.—The ore found in the Franklin limestone occurs in a variety of forms. In some places,

as at the Ahles mine, it constitutes a comparatively thick layer of uniform width running for a long distance without interruption. As has already been related the ore consists essentially of a mixture of magnetite crystals and grains in a soft earthy limonite.

In other cases, as at the Glendon mine, the ore is apparently in an irregular-shaped mass that is so involved with black dioritic rocks that its outline is impossible to decipher. The ore in this case is mainly a mixture of magnetite, garnet and calcite. Moreover, in this case, as in other similar cases where there has been an intrusion of basic igneous rocks, the limestone is impregnated with magnetite crystals for considerable distances beyond the ore body proper. Consequently the ore body, or that portion of it which was considered to be rich enough to work, graded into the surrounding limestone by almost imperceptible transitions.

A third type of ore body in the limestone is represented by the Sulphur Hill mine near Andover. Here the ore body is also irregular, though in rude lens-shaped masses, striking northeast and dipping southeast. When the mine was in operation it was reported that the ore occurred in "shoots" pitching northeast; *i.e.*, the ore bodies were conformable with those in the neighboring gneisses. The quantity of limestone associated with the ore was so small that the mine occupies a position intermediate between mines in gneisses and those in limestone.

The ore of this mine is characterized by a high percentage of pyrite and by the fact that it is a mixture of minerals unlike that anywhere else in the Highlands. Sulphides are abundant, among them being galena, sphalerite and chalcopyrite in rather large quantities. Willemite and garnets are also present, the latter in several varieties. In general the ore deposit is unique among the magnetite deposits, and because it is so different from these others and so similar in many respects to the zinc ore deposits at Franklin Furnace and Sterling Hill its history is believed to be different in some respects. It is thought that it may be a replacement of small masses of limestone embedded in the gneisses, as the result of the action upon it of solutions, gases and vapors emanating from the igneous rocks associated with it.

Ore Bodies in the Gneisses.—The ore bodies associated with the prevalent gneisses of the Highlands are by far the most valuable in the State. Practically all of the important mines are situated upon them. For short periods certain mines have worked pegmatites. Others have exploited for longer periods the ore bodies in the Franklin limestone. All these, however, have sooner or later been abandoned and only those mining the ore in the gneisses have proven permanent. Among the latter may be mentioned the Dickinson, the Hurd, the Richard, the Stirling, the Hibernia, the Oxford, the Mt. Hope, and the Ringwood mines. All these, with the exception of the Hurd mine, at Hurdtown, are still active shippers and all have been worked successfully for nearly 100 years.

The ore-bearing rocks in the gneisses occupy the same general relations to the surrounding rocks as do the layers of Pochuck gneiss to the lighter-colored gneisses. They constitute thin layers striking and dipping with the associated gneissic rocks and wedging out at their ends when not terminated by faults. In some instances the contacts with the adjacent gneisses are sharp, but in many cases the ore layers and the country rock grade imperceptibly into each other. On the surface the trace of the magnetiferous layers can be followed for considerable distances by their weathering products which extend across country in straight lines as rusty-red streaks made up of hornblende, biotite, quartz and limonite. These layers, which are known as the ore "veins," contain rich and lean portions, the former of which are the ore bodies. Where not deeply weathered the veins differ very little from the ordinary Pochuck gneisses, except that they contain a greater proportion of magnetite.

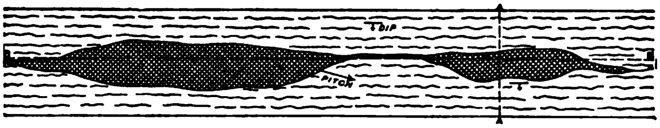
The ore-bearing layers vary in thickness from a small fraction of an inch to 50 or more feet, the average thickness being from 4 to 20 feet. They occur in narrow belts or ranges separated by wider belts of barren gneiss. The width of the ranges is rarely more than 2 miles and is usually less than one-half mile. Their lengths are indeterminate at present because of lack of knowledge. Their productive portions in some cases attain lengths of 30 miles or more, but more frequently than otherwise they are less than 1 mile long. These ranges may be regarded as mineralized zones.

Within the ranges there may be a single ore-bearing layer or vein or there may be several parallel veins of large size and numerous small ones so thin as to be unworkable.

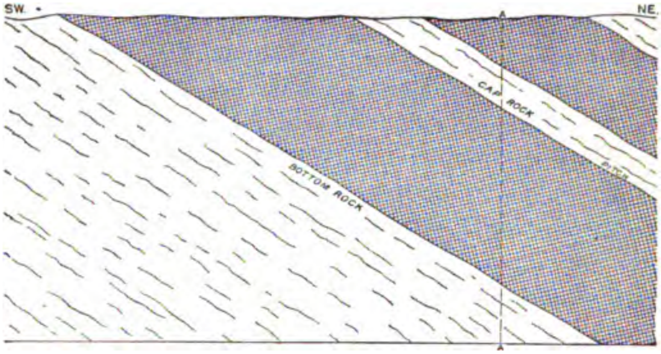
The developed portions of the veins vary greatly in length. Some, judged from their outcrop, are extremely short, perhaps being limited to the length of a single ore body. Others are 300 or 400 feet long and may contain a succession of several ore bodies. The Hibernia vein has been developed for at least a mile in length, and, if the vein at the Montauk and Beach and the White Meadow mines to the southwest is in the extension of the same vein as they are thought to be by most miners, its entire length is over 2.5 miles. In the Hibernia portion of the vein there are reported to be 10 or 12 shoots and a corresponding number of pinches.

SHAPE AND SIZE OF THE ORE BODIES.

The ore bodies are portions of the ore veins that are rich enough in magnetite to warrant mining. Practically all the rich ore bodies are distinctly pod-shaped lenses, with the longitudinal planes of the pods dipping parallel to the dip of the layers of the neighboring gneisses and their longer axes pitching with the pitch of the rock structure (Fig. 5). Ususally a number of the lenses lie one above the other in the same plane, all pitching and dipping in the same direction. This feature is well illustrated in the Ford and Schofield mines at Ford, in the Harvey, Hurd and Orchard mines at Wharton, in the Peters mine at Ringwood, at the Mt. Pleasant and Richard mines at Wharton, and at the Mt. Hope mines. The pods, whether isolated or in series, are known as shoots and the comparatively barren vein rock between them as pinches. The rock overlying the shoots—*i. e.*, that under which the ore pitches—is called the "cap" rock and that under the shoot the "bottom" rock. The hanging wall is that under which the shoots dip and the foot wall that over which they lie. The material of the shoots grades into that of the vein rock by the loss of magnetite. When the magnetite is not sufficient in quantity to make an "ore," mining ceases and the material is considered "rock." The succession



a.



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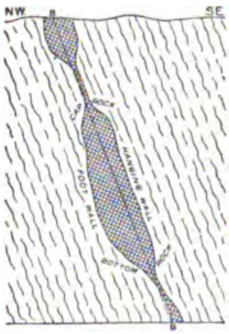

c.

Fig. 5.

Diagrams of pod-shaped ore shoots characteristic of the magnetite deposits:
a, Plan of ore lenses.
b, Longitudinal section of same in the plane of the dip, along the line B–B in *a.*
c, Vertical cross section along the line A–A.
(From Folio 157, U. S. Geol. Survey, 1908, p. 24, and Geol. Atlas of N. J., Folio No. 1, 1908, p. 24.)

of shoots and pinches in their horizontal direction constitute the outcrop of the vein. Where the limits of the vein coincide with the planes of junction between bands of gneiss its bounding walls are sharply marked; where the boundaries of the vein and

the junctions between gneiss bands are not coincident the walls are not distinct, but there is a gradation between ore and rock.

The pinches, though poor in ore, are not entirely barren. In some instances walls of the veins close in, reducing the width of the ore bodies to a few feet or even a few inches; but more frequently the space between the "shoots" is occupied by vein rock, which in some instances is a pegmatite full of magnetite, in other instances is country rock (gneiss) traversed by a few or by many narrow strings of magnetite, connecting the shoots with one another, and in still other cases is a coarse hornblende cut by tiny veinlets of ore running parallel with the general direction of the gneisses.

In one or two places, notably at the Ford and Scofield mines, and at the Weldon mine, there were parallel shoots, which so far as we know are entirely independent. As mining proceeded downward the ore bodies at the Ford mine approached one another until a distance of only five or six feet separated them. At one time it was supposed that they would unite below. As mining progressed, however, they again separated and continued to maintain their independent entities.

The occurrence of the ore in shoots between pinches has already been referred to. The shoots have been described as pod-shaped masses that occur in series dipping with the dip of the associated gneiss and pitching parallel to the pitch of their structure. As a matter of fact, the ore bodies are not always as simple as this. The pinches are of various kinds and these determine in part the shapes of the shoots. In the State Report of 1883 the manner of production of the pinches is outlined at considerable length. From it is quoted the following:

"The *pinches* in the ore are caused in some cases by irregularities in both walls. And they converge or approach one another by irregular rolls and the ore is squeezed into the thinnest recognizable layer or sheet. A peculiar form of *pinching* is caused in some cases by a flattening of the walls, but not so as to produce a parallelism, and the result is a narrowing of the *vein* into pinches. * * * * Examples of it are to be seen in the Kean Mine, near Chester, and at Mount Hope, besides other localities. Rarely are the walls found coming together so as to pinch out the ore completely. As it is not profitable work to follow so thin leads and pinched-up veins, miners and practical men speak of the ore as pinched or cut out even in such cases. But it is more often the fact that the pinch is caused by rolls in the foot

wall, the hanging wall retaining its regular dip and strike. The foot wall is seen to grow flatter and approach the opposite wall, by a series of step-like *offsets,* which are sometimes called *rolls* and sometimes *slides of rock.* When both walls have rolls of this nature and are not strictly parallel, a succession of shoots and pinches is produced. Following the ore lengthwise the shoot-like irregularities in the walls are observed to produce pinches between the end of one shoot and the beginning of another. The walls here may approach each other at uniform angles, or, what is generally true, a succession of slabs of rock come in on the foot wall and leave no room for the ore shoot, and a pinch results."[1]

The shoots, moreover, are not uniform throughout. Often a slab of rock, or a horse, divides the ore mass into two parts

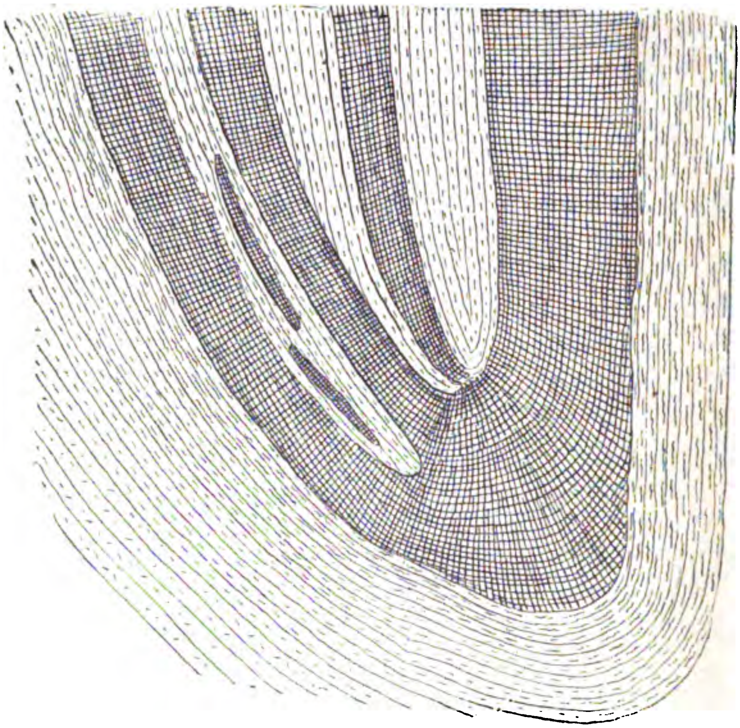

Fig. 6.

Sketch showing relation of ore and gneiss in the wall of the southwest opening of the Hurd mine at Hurdtown. (From Ann. Rep. State Geologist N. J. for 1883, p. 59.) Crossed lines indicate ore. Parallel lines represent rock.

[1] Ann. Report State Geologist N. J. 1883, p. 69–70.

which may remain separated for long distances. In other cases the slab may project into the ore-body from below or above, separating it into two parts which may have the appearance of the limbs of a fold. At the Hurdtown mine, on the northeast wall of the old southwest opening near the turnpike, the ore body is said to have exhibited a genuine folded structure (Fig. 6). The folded ore body pitches to the northeast and hence the outcrop which is represented in the figure is the cross section of a syncline whose axis descends to the northeast. The long slope of the mine followed the line of the axis. A notable feature of the supposd fold is the difference in character between the two limbs. The southeast limb was thick and compact. The northwest limb on the other hand was split into three thin portions that were separated by two layers of rock. These have every appearance of being horses that project downward into the ore bodies, and it is a question whether the central rock mass which is supposed to separate the two limbs is not another horse. The bottom of the ore body has not been studied, so it is not certain that the underlying rock is not a bottom rock into which some of the ore material projects. No other such clear suggestion of folding has been seen anywhere else, although in the Richards mine the ore body at one place appears to curve in such a way as to resemble a fold, and at the Hurd mine at Wharton an ore spur extends from the main ore mass downward a distance of 80 feet. Phenomena of a similar character have been described from other mines, but in all cases it is thought they may be explained as features connected with the origin of the ores rather than as the result of the folding of the ore layers subsequent to their formation.

The sizes of the shoots vary greatly. Along their pitch, they may persist for considerable distances. At the Hurd mine at Hurdtown, the length of the ore-body from its outcrop to its underground termination was more than 6,000 feet, but this was exceptional. A length of 1500 feet for a single ore pod is not unusual, but lengths of 400 or 500 feet are more common. In their horizontal dimensions the shoots are more uniform. Their widths, measured at right angles to their strikes, vary between

a few inches and 40 feet, and their breadths measured in the planes of the veins are approximately 125 feet.

Cap and bottom rocks are supposed to terminate the horizontal extension of the ore bodies along the strike, so that beyond them no continuation of the shoots is to be expected. As a matter of fact, however, true cap or bottom rocks have been proven to exist in only a few cases. At times it was supposed they had been encountered in the more important mines, but close observation has shown that the ore bodies extend into them as tiny streaks of magnetite, and subsequent persistent exploration following these streaks as "leaders" has developed beyond them new and unexpected ore bodies. In all cases where the ore bodies have appeared to terminate suddenly this has been due to cross faults which have displaced the vein to such a distance that persistent search has failed to discover its continuation.

FAULTING OF THE ORE BODIES.

Where faults exist the horizontal displacement caused by them is nearly always to the right; *i. e.,* toward the hanging wall on the southeast when facing northeast (Fig. 7), and is usually only slight in amount, although in some cases it reaches at least 200 feet, and in a few others it must be much

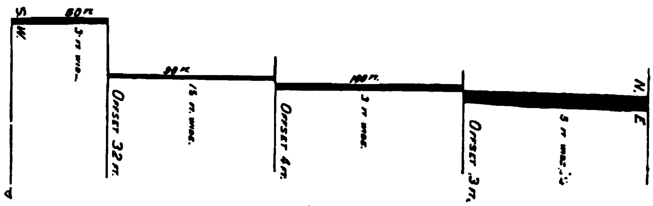

Fig. 7.

Plan of faults at the Randall Hill mine. (From Ann. Rep. State Geol. N. J. for 1883, p. 63.)

greater, since ore bodies that have been mined up to the fault plane have been entirely lost on its opposite side, all attempts to find them with diamond drills within a reasonable distance on both sides of the projected strike of the ore having failed.

Faults causing displacements to the left are comparatively rare, although they are met with in some of the mines. Figure 8 illustrates the horizontal plane of the ore body at the Mt. Pleasant mine where the displacements are alternately to the left and to the right. Most of the faults that have been observed cross the

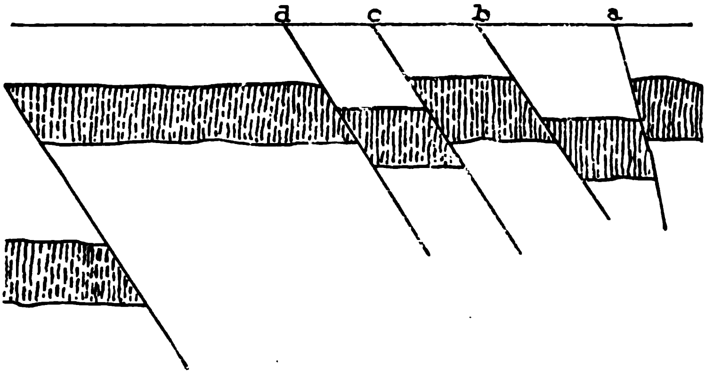

Fig. 8.

Horizontal section at S. W. end of Mt. Pleasant mine, showing displacement of ore body caused by faulting. (From Second Ann. Rep. Geol. Survey N. J. for 1855, p. 203.)

ore veins either perpendicular to their strike or at a very large angle with this, so that their direction is approximately northwest or in some direction between west and northwest. Their dips are usually very steep. In some cases the dip is vertical, but more frequently it is inclined 15°-20° from vertical, the inclination being in some instances to the northeast (*d* and *e* in Fig. 9), and

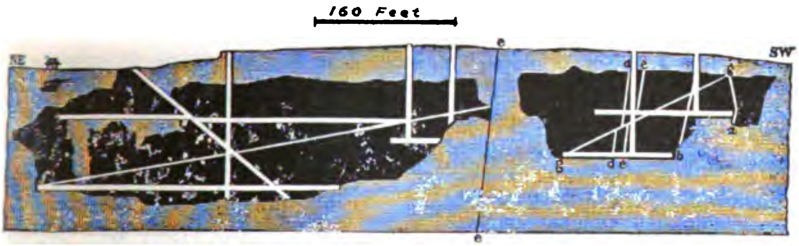

Fig. 9.

Vertical longitudinal section of Mt. Pleasant Mine. October, 1855. (From Second Ann. Rep. Geol. Survey N. J. for 1855, p. 202.)

The part in black represents the portion of the ore that had been removed. The heavy white lines are shafts and levels, and the lighter lines are faults.

in others to the southwest. If the old mine plots can be relied upon the direction of movement along the fault plane has also varied. While usually the downthrow has been on the southwest side of the fault and the horizontal displacement has consequently been to the right, the opposite condition has sometimes prevailed. Moreover, the hade of the fault gives no indication as to the direction of throw. For instance, in the Byram mine (Fig. 10)

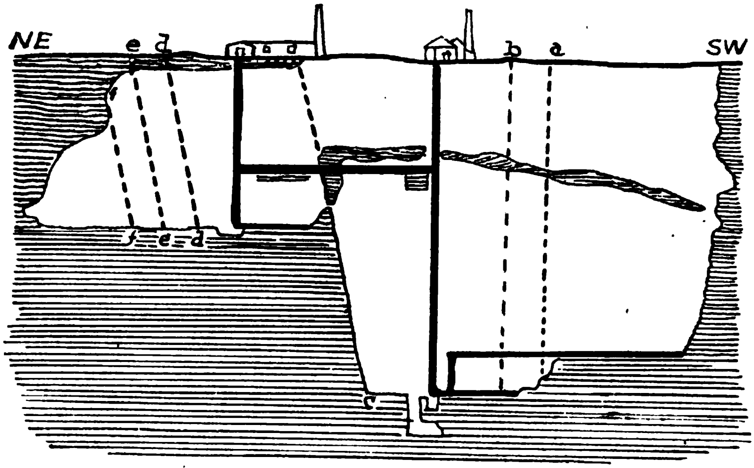

Fig. 10.

Vertical section of Byram mine, October, 1885. (From Ann. Rep. Geol. Survey for 1855, p. 212.)

Dotted lines represent faults. Unshaded area, ore removed. Shaded area, ore and rock. Heavy black lines, slopes and drifts.

the dip of the faults is to the southwest and their hanging walls are on the upthrow side (*i. e.*, the northeast side is the downthrow side), causing a displacement of the ore body to the left. At the Mt. Pleasant mine (Figs. 8 and 9), on the contrary, most of the faults dip northeast. Their displacement varies. About some of the faults the downthrow side is on the southwest, and about others it is on the northeast side. At the Irondale mines, again, the displacement about one fault is to the right and about another to the left. (See page 387.) At the Randall Hill mine there are three faults and each has caused a right-handed displacement (Fig. 7). Between Mt. Hope and Hickory Hill the displacement on the surface has been 160 feet to the right (Fig. 11),

Fig. 11.

Sketch map of Mount Hope and Hickory Hill, showing displacement of ore veins by faulting. (From Ann. Rep. State Geol. N. J. for 1886, p. 99.)

which indicates a downthrow of about 450 feet on the southwest side of the fault on the supposition that only vertical movement has taken place. At the Hackelbarney mine a fault crosses the ore body with a vertical dip. The throw here is also to the right (30 feet), the downthrow side being on the southwest. At the Hurdtown mine the ore body seems to have been faulted 150 feet vertically by a fracture dipping steeply to the southwest, the downthrow being on the hanging-wall side and in the direction of the dip of the ore veins.

A second class of faults consists of those that strike nearly parallel with the ore beds and dip at various angles to the northwest, the downthrow being on the foot-wall side. (Fig. 12.)

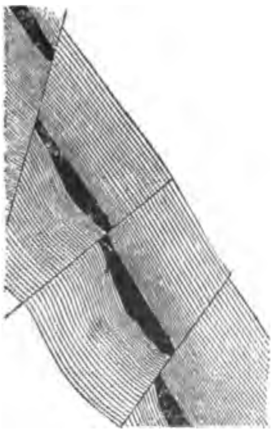

Fig. 12.

Vertical cross section of the Mt. Pleasant Mine, looking northeast. Showing strike-faults. (From Ann. Rep. State Geologist, N. J., for 1883, p. 65.)

The movements along the fault planes have usually resulted in clean surfaces. Sometimes the rocks near the fault are sheared and the fault surfaces are slickensided. In a few other cases, as for instance at the Richard mine, the fault crack is apparently occupied by a thin seam of ore.

These faults because of their similarity to those in the Newark rocks may be fairly regarded as having been produced in Newark time.

DISTRIBUTION.

No definite rule as to the distribution of the ore-bearing layers can be formulated. They may occur within wide layers of Pochuck gneiss, they may be surrounded entirely by Losee or by Byram gneiss, or they may have walls of different gneisses. In a few cases, as has already been indicated, the neighboring rock may be the Franklin limestone, and at one place—in the vein at Franklin Furnace—limestone is present on one side of the ore deposit and gneiss on the other side. The existence of the ore "veins" is therefore independent of the character of the country rock. Their positions, however, are so distributed that they may be described as occurring in zones, between which are stretches of barren country in which only sporadic ore bodies have been discovered.

The belts of veins are not sharply defined. They consist of assemblages of parallel veins, each of which may be short, but all of which taken together form a zone which in some instances extends entirely across the State, from the Delaware River to its northern boundary. On these belts or zones are situated most of the mines that have been prominent as contributors to the State's output of ore. A few others lie between the belts, but none of them have risen to prominence. As a rule the country between the belts is practically barren from the ore producer's view-point. (See accompanying large maps.)

So far as is now known there are no structural features that determine the position of the belts. No great faults that have been recognized extend along their lengths, though numerous small ones are known to cross them. Further, the belts are not

in crush zones, for the rocks associated with the ore veins show no more granulation than the similar rocks between the belts. Since there are no known lithological or structural features that condition the position of the ore bodies it is impossible to predict their existence from anything seen on the surface, except in places where the ore bodies outcrop.

CHAPTER VIII.

ORIGIN OF THE NEW JERSEY MAGNETITES.

In this chapter the conclusion of the author as to the origin of the New Jersey magnetites is first given. It is followed by a brief history of the investigations and conclusions of previous workers in the same field. Finally there is a summary of the conclusions reached by various investigators of magnetite deposits in other districts. In presenting the latest view first, violence is done to the historical order of presentation, but it has the advantage of presenting first to the reader's attention the view which at present seems best founded.

SECTION I.

PRESENT VIEW AS TO ORIGIN.

From the statements made in the preceding chapters it will be observed that the magnetite in the New Jersey Highlands occurs, 1) disseminated as individual grains through the prevailing gneisses of the district; 2) as small bunches in these gneisses; 3) as an important component of some of the pegmatites associated with the gneisses; 4) as a prominent constituent of certain zones in the Byram and Losee gneisses; 5) as an important component of certain layers of dark hornblendic rocks resembling the Pochuck gneisses; 6) as narrow dike-like masses of pure magnetite traversing the gneisses in the direction of their banding; 7) as deposits of mixed magnetite, limonite and pyrolusite in the Franklin limestone; and 8) as irregular aggregates of magnetite,

garnet and other silicates, and often some sulphides, associated with basic instrusive rocks in the limestone.

The ore-bodies in the gneisses—that is, the portions of the ore veins that are rich enough in magnetite to possess a commercial value at the present price of iron—are usually lenticular in shape, and their material may or may not grade into the surrounding rocks that are comparatively poor in magnetite, although practically all of them contain more or less of this component. The ore-bodies, or shoots, are arranged in belts dipping and striking with the layers of the surrounding gneisses. Between the shoots in any belt are masses of barren rock which is usually either a pegmatite or a rock composed of hornblende and pyroxene. This is often traversed by narrow seams of rich ore connecting successive shoots. The shoots, together with the barren rock between them, constitute the ore-veins, which are usually sharply separated from the surrounding country rock. In some cases the shoots form such a large portion of the vein that the latter is practically a vein of rich ore. There is no regular arrangement of the minerals in the vein, nor is there any gangue in the sense in which this term is commonly used, *i. e.*, material in which the magnetite is embedded. In some cases there is a regular banding of magnetite and gneiss, but in these instances the gneiss is the usual country rock and there is no differentiation of vein and rock.

The ores in the limestones present many of the same features as those in the gneisses. The shoot structure is perhaps not so well defined, nor is there in most cases as distinct a vein. The conditions are often complicated by the presence of intrusive basic rocks, which have evidently metamorphosed the limestones and brought about an intermingling of metamorphic minerals with the normal components of the ores.

The only accumulations of magnetite having commercial importance are those in the pegmatite (3), those in the black gneisses (5), and those in the limestone (7 and 8). In a few instances zones of gneiss impregnated with magnetite (4) have furnished a lean ore, but these are no longer worked. At the present time only one mine is exploiting a limestone deposit and that is of the type designated as No. 7 above, though

formerly the deposits in the limestone were of considerable importance. Most of the ore at present being worked is of the 5th type. It is a mixture of hornblende, augite, feldspar, quartz and magnetite. In a few instances these ores are nearly pure magnetite within restricted limits, but even in such cases there is usually intermingled with the magnetite a little feldspar and hornblende.

It is quite evident from the character of the different types of ore that they have all had the same origin. The ores in the limestone differ somewhat from those in the pegmatite and the gneisses, but these differences are easily accounted for by the character of the country rock. In all cases the ores are regarded as being of magmatic origin—that is, the source of their material is thought to have been the deep-seated molten magmas, portions of which, upon being intruded into the overlying rocks, solidified as the various gneisses now constituting the principal rocks of the Highlands ridges. After the partial cooling of the gneisses these were in turn intruded by ferruginous portions of the same magma that gave them birth, and these intrusions were later enriched by iron-bearing solutions or vapors originating in the same subterranean source. In their transit to the surface these solutions or vapors deposited additional magnetite in the intruded ferruginous rocks and made the ore lenses that now comprise the ore bodies.

The evidence in favor of this theory is not by any means conclusive, but it is the only theory that suggests itself which will account for most of the facts observed in connection with the distribution and manner of occurrence of the ores. Moreover, it is in accord with the views held with respect to the origin of similar magnetites elsewhere. The principal reasons for accepting it are indicated below.

The magnetite which occurs as a constituent of the gneiss is plainly a separation from the magma that yielded the rock. It was one of the first components to separate, and in all of its features presents the normal appearance of a rock constituent. The magnetite that occurs as small bunches in the gneiss is apparently also a segregation from the rock magma. The material of the bunches often passes into that of the surrounding

rock by gradual transitions. From these deposits the transition is also gradual into the ores of the 4th group, which consist of phases of Losee and Byram gneiss sufficiently rich in magnetite to raise their iron content above the lower limit of workable ores. Thin sections of these ferruginous gneisses exhibit no noteworthy peculiarities. They differ from the sections of the more usual phases of the gneisses mainly in showing the presence of a greater amount of magnetite. This mineral often exhibits the outlines of crystals and in its relations to the surrounding minerals presents the same features as the magnetite scattered more or less abundantly through the more normal gneisses. It is apparently a separation from the rock magma in the same way as are the other rock components. The greater abundance of the magnetitic phases in some places than in others is accounted for in the same way as is the irregular distribution of more acid and less acid phases of the gneisses, or phases in which hornblende is scarce and those in which it is abundant, *i. e.*, by successive intrusions of differentiated portions of an originally uniform rock magma. In many instances the ferruginous gneisses are banded, layers of rock rich in magnetite alternating with those containing only small amounts of the mineral. This interlayering is identical in character with the interlayering of the tabular masses of the different gneisses which is such a conspicuous feature of the geology of the district, and, like it, is ascribed to successive intrusives of material of slightly varying composition. It is possible, however, that the banding has been emphasized and made more prominent by deposition of magnetite from circulating hot water that followed the gneissic foliation. Such deposits would occur most abundantly in the planes separating the different rock layers and would thus enrich certain belts as compared with others.

In the pegmatites the magnetite is in three forms. It occurs 1) as large irregular sub-crystalline grains between the other rock components, 2) as well-defined crystals embedded in feldspar and hornblende, and 3) as angular masses filling the spaces between feldspar and quartz grains. Often the feldspars present crystal outlines where they are in contact with magnetite, and tiny veinlets of the latter mineral penetrate the cleavage cracks

of the former. The magnetite is thus in two generations, the first of which crystallized before any of the other constituents of the rock, and the second after all the others had been formed. The particles of the first generation were clearly products of the crystallization of the magma that solidified as pegmatite. This is believed to be a differentiate of the magma that gave rise to the prominent gneisses of the district, and as such is a part of the gneissic complex. It was the last portion of the magma that was intruded, and, like many pegmatites elsewhere, was probably formed by the crystallization of an aqueo-igneous solution, the source of which was in the cooling magma. Zircon and fluorite are often present in the pegmatite. Garnet is found in a few cases and sphene and apatite are nearly always present. With the exception of the garnet, these minerals are characteristic[1] of aqueo-igneous deposits and lend support to the view that the pegmatite possesses this mode of origin. The later magnetite, which is in the nature of a subsequent enrichment, was evidently introduced after the normal components of the rock had crystallized. It occupies the interstices between these, and in some cases was deposited in the cleavages of the feldspar, where it now appears as extremely thin sheets penetrating the silicate as tiny veins. It is evident that the iron was in a very fluid form, otherwise it could not have been carried into the crevices which it now fills. Very probably the vehicle of transportation was a hot aqueous solution or possibly a vapor which emanated from the same magmatic source as the material that produced the pegmatite. It succeeded the latter, first appearing after the temperature had fallen below that of aqueous fusion of the silicates. The channels through which the solutions circulated presumably afforded the most favorable opportunities for deposition of mineral matter, and such portions of the rock naturally became richer in magnetite than other portions through which the solutions slowly percolated, and thus became the ore shoots. In some places there may have been replacement of the silicates by magnetite, causing further enrichment of the mass, since in some of the ore shoots where the ore appears to occupy the entire breadth

[1] Economic Geology, Vol. 2, No. 2, p. 111 and 121.

of veins for long distances there may occasionally be detected in the otherwise pure magnetite well-outlined crystals of feldspar and hornblende and scattered round grains of quartz.

The fact that the solutions invaded the belts of pegmatite in preference to belts of gneiss is accounted for by the supposition that the pegmatite magma had not entirely cooled at the time the iron-bearing solutions were extruded, and, therefore, was more or less pasty, while, on the other hand, the gneisses were cold and solid. The process of extravasation was thus a continuous one, beginning with the siliceous magma that yielded the magnetite-bearing pegmatite and ending with the vapors that deposited magnetite, fluorite, zircon and possibly some of the compounds of the rare metals—molybdenum, vanadium and uranium.

The reason for the constantly recurring pitch of the ore bodies to the northeast is not understood. Since, however, this direction always conforms with the direction of pitch in the neighboring gneisses, its origin is thought to be regional in character, *i. e.*, it is thought to be due to some cause that operated nearly uniformly over the entire Highland district.

The ore bodies in the dark gneiss which are of so great commercial importance probably had an origin analogous to that of the ores in the pegmatite, except that in the first stage in ore production the intrusion of very acid siliceous material was lacking. In a few cases pegmatitic material is intermingled with the magnetite in the dark gneisses, but usually the vein matter consists of hornblende, augite and magnetite with a little quartz and sphene, the whole constituting the dark layers that are interleaved with the lighter-colored rocks. The hornblende and magnetite in these layers are often found intercrystallized, the latter being enclosed within the hornblende crystals, and in other places filling the spaces between adjacent hornblende and pyroxene. This magnetite is clearly the product of the crystallization of the magma which formed the dark layers. The ore and the amphiboloids thus constitute a rock mass which becomes an ore when the magnetite predominates, as is the condition in the shoots. In the pinches between the shoots the hornblende and pyroxene predominate and the magnetite is in small quantity. Through these pinches, however, there often extend small

stringers of almost pure magnetite, which appear in cross-section as narrow dikes from a small fraction of an inch to several inches in width running parallel to the general strike of the vein. Their contacts with the surrounding rock are not sharp, their similarity in appearance to well-defined dikes being very superficial. There can, however, be no doubt that the material of these bands is distinctly younger than the material which it apparently intrudes, and that it was deposited by solutions passing between the ore bodies.

The ores in the Pochuck gneiss thus present the same essential features as those in the pegmatite. There is a later magnetite and an earlier one. The earlier one is one of the original constituents of the cooling magma. The later corresponds to the second generation of magnetite in the pegmatite. Like this, it is probably a deposit from a hot aqueous solution, which, where it traversed the magnetite-bearing Pochuck gneiss, formed ore bodies. These constitute the shoots where they occupy main channels. Where they occupy small crevices they form the veins or dike-like streaks that traverse the comparatively lean pinches and unite the shoots with one another.

Besides the belts of Pochuck gneiss that have a magmatic origin there are other, older, dark gneisses into which the magmatic gneisses were intruded. The origin of these is doubtful. They may be old igneous rocks, or they may be metamorphosed beds of tuffs or sediments. It is not certain that any of the ore bodies are associated with these older gneisses. Since, however, it is difficult to distinguish these older black gneisses from the later ones it is possible that some of the gneisses associated with the ore may be of this kind. If there are any ore bodies in these gneisses, they cannot be distinguished from those in the magmatic gneiss, nor is it probable that their mode of origin can have been very different.

Only one other type of ore remains to be considered. This is the type that occurs in the Franklin limestone. The ore in the limestone differs from that in the gneisses only in so far as it is affected by the difference in the character of the rock by which it is enclosed. The black hornblende and pyroxene that are characteristic associates of the ores in the gneisses are rare in those

in the limestones, and calcite becomes the prominent gangue mineral. On the other hand, colorless or light-green pyroxene, garnet, micas and occasionally other silicates that may have been produced by metamorphism of the limestone are frequently met with in the ores. In some cases there is much limonite intermingled with the magnetite and in this are nodules of pyrolusite. Moreover, practically all of the limestone ore is manganiferous. In most places the ore bodies in the limestone comprise shoots that are similar to those in the gneisses, but at the Ahles mine the mixed magnetite and limonite form a dike-like mass with straight walls extending for a considerable distance without the shoot and pinch structure that is so noticeable in the mines in the gneiss. The absence of this structure may be due to the fact that development of the ore body has not proceeded far enough to disclose it—that the mining has thus far been on a single shoot of great size. In the ore of this mine there are a few decomposed feldspar crystals—now changed to soft kaolin—and a few doubly terminated crystals of quartz. There are also large nodules of ferruginous chert enclosing pockets of limonite and crystals of magnetite. Further, some of the limestone near the ore body has been silicified so that it now resembles very closely a light-gray gneiss.

The Ahles mine differs notably from the Sulphur Hill, Roseville, Glendon and several other mines in the absence from it of intrusive basic rocks. In the latter case the presence of these intrusives is accompanied by the presence of garnet, various sulphides and silicates like chondrodite, diopside and serpentine derived by the metamorphic action of the intrusive rocks upon the limestone by which the ore bodies are surrounded. In the case of the Ahles, the Queen and other mines in the limestone near Pequest, where basic intrusive rocks are lacking, these metamorphic products are also lacking.

The origin of the magnetite bodies in the limestone is probably the result of the same two processes already outlined in connection with the ores in the gneisses. The magnetite was probably introduced into the limestone by intrusion of aqueo-igneous material emanating from deep-seated sources, and during this process the limestones near the ores were silicified and garnets were

produced. The acid portions of the magma reacted upon the limestones with the formation of lime silicates, and, consequently, did not take the form of pegmatite as it did in the gneisses, although here and there, as has already been related, a few feldspar crystals and grains of quartz scattered through the ore bodies give evidence of the siliceous character of the ore-depositing agency. The hot solution which followed the aqueo-igneous intrusions added more iron and enriched the ore bodies partly by depositing additional magnetite in the ore veins and partly by replacing the calcite adjacent to the ore bodies. Isolated magnetite crystals are found scattered sparsely through the limestone at some distance from the ore bodies. They become more and more numerous as the ore bodies are approached, and very near these they form large clumps thickly studding the limestone. At the Ahles mine and the other mines in its vicinity the magnetite in the ore body is embedded in limonite in which are also little nodules of pyrolusite, but at most of the mines in the limestone in other portions of the Highlands, magnetite, calcite and the various silicates associated with those minerals in the ore vein form a compact mass in which neither limonite nor pyrolusite can be detected. The form in which the manganese is present in these ores is unknown. The analysis of the magnetite separated from the ore of the Ahles mine (page 111) shows that it is present only in comparatively small quantity. It is, therefore, inferred that the element may have been disseminated in the rock before it was invaded by the intrusions from below.

At the Ahles mine and the others in its vicinity the mixture of limonite and pyrolusite is thought to be the result of the replacement of the limestone that otherwise would have appeared as the gangue of the ore, by the ascending ferruginous solutions, and the subsequent oxidation of the resulting mixture by downward percolating meteoric water. The exact steps in the process have not been ascertained. It is probable that the result of the action of the ascending solutions was the deposition of magnetite and the production of iron and manganese carbonates by the replacement of limestone, and that the effect of the descending water was analogous to that which takes place in the production of

bog-ore. Fragments of the ferruginous limestone taken from the dumps of the Queen and the Little mines when dissolved in small quantities of dilute acetic acid yield residues consisting largely of magnetite, limonite and manganese oxides.

SECTION II.

BRIEF HISTORY OF THE STUDY OF THE NEW JERSEY ORES.

The first references to the geology of the Highland region in New Jersey and to the iron mines situated in the northern portion of the State are found in several papers published in 1822. In one of these James Pierce[1] described the rocks of the Highlands as granites and schists, and incidentally mentioned the fact that mines were being worked in the Pompton Mountains, at Rockaway and at Succasunna. He also referred to the Copperas mine and stated that the Dickinson mine furnished excellent ore. In the same year Thomas Nutall[2] described the limestones and the metamorphic minerals in the ore beds at Franklin and Sparta and made special reference to the magnetite under the furnace built to smelt the zinc ores at Franklin Furnace. L. Vanuxem and W. H. Keating[3] also described the Franklin Furnace zinc deposits and proclaimed the rocks associated with them to be primitive in age and to comprise sienite, limestone, gneiss and greenstone. The sienite and limestone were reported to occur in beds and in the latter rock were observed thin layers of magnetite. Overlying these was found a graywacke (quartzite) and a gray limestone, both of which were regarded as younger than the sienite series. The gray limestone was thought to be equivalent to that at Easton and Reading, and in the valley north of Schooley's Mountain, a view which later observers proved to be correct.

It was not until eighteen years later that Henry Rogers, in his final report as State Geologist, gave the first detailed description

[1] Amer. Jour. Sci. (1) Vol. V, 1822, p. 26.

[2] Ib. (1) Vol. V, 1822, p. 239.

[3] Journal of Acad. Nat. Sci. of Philadelphia, 1822, Vol. II, pp. 277-288.

of Highland geology.[1] He described the ridges as anticlinal folds of sedimentary gneisses with the rocks on opposite sides of their axes dipping away from each other.

They were correctly considered as being unconformably beneath Paleozoic beds. He described the rocks in detail in much the same terms as would be used in describing them to-day, and gave an excellent account of their structure. He, however, considered the white limestone associated with the gneisses as metamorphosed phases of the blue Paleozoic limestone, a view which is discredited at the present time. The magnetite veins were referred to as "genuine lodes or veins" lying between walls of granitoid gneiss to which they are parallel, not only in strike but in dip. He called attention to their variation in width, the inclusion in them of "horses" of the neighboring rocks and the occurrence of the ore bodies in distinct pods. His conclusion as to their origin is given in the following words:

"The several circumstances here spoken of in the structure of these metalliferous veins, seem strongly to imply that they are real veins of injection, and not true beds, contemporaneous with the adjoining gneiss, as some have supposed" (p. 22),

and,

"the first theoretical inference, naturally suggested by the remarkable manner in which all the veins, without any exception, occur, is, that the primary strata existed in all probability at a rather steep inclination before the intrusion of the veins; for it is inconceivable how a forcible injection of fluid ore could enter a series of beds, lying in a nearly horizontal position, without in some cases causing and occupying fissures transverse to the strike of the strata. The fact that other similar veins—those of the altered white limestone of Sussex—occupy a corresponding position in reference to the neighboring strata, and appear to have been produced after the formation of the limestone, is another argument lending probability to the notion that their origin was subsequent to the formation and upheaving of the gneiss." (p. 36).

As to the age of the ore, he says:

"In examining the question of the date of the veins of magnetic iron ore, our attention is at once called to the interesting general fact that these veins lie exclusively in the primary rocks. I think we must conclude that most, if not all of these veins of ore, were extruded from their deep source beneath the surface during the epochs which preceded the deposition of the first widely dispersed secondary [Paleozoic] strata."

[1]Final Report on the Geology of the State of New Jersey, Philadelphia, 1840, pp. 12-22 and 36.

This was the first published declaration as to the genesis of the magnetites. Rogers' views have been accepted by very few of the geologists who succeeded him in the study of the New Jersey ores. Most of these believed the ores to be sedimentary.

In his discussion of the ores the author mentions the names of a number of mines, among them the Ringwood, Hibernia, Mt. Hope and Oxford groups, and the Charlottesburg, Dickinson, Sweed, Muir, Jackson, Denmark, Teabo, Mount Pleasant, Harvey, and Stirling mines and a number of explorations that afterward developed into shipping mines.

In the succeeding fifteen years there was but little reference in the literature to the Highland geology. C. T. Jackson[1] incidentally referred to the syenite and the white limestone associated with the Franklin ore deposits as being in his opinion igneous in origin, and mentioned the names of some of the old mines, but he added little to the knowledge of the origin of these ores.

With the establishment of the second survey of the State, however, the view held by Rogers as to the igneous character of the ores began to be attacked and the theory of their sedimentary origin was proposed.

William Kitchell,[2] who followed Rogers some years later as State Geologist, published three reports. In the first, issued in 1855, he discussed in some detail the physical geography and geology of Sussex County as typical of the northern part of the State. The pre-Cambrian rocks he divided into a metamorphic series, which included gneiss, hornblende, slate and white limestone, and an igneous series including veins, dikes, and irregular masses of granite, syenite, and a quartzose feldspathic rock that cut the metamorphic series.

He also described the ores as magnetite, mixed with quartz, mica, hornblende, and feldspar, occurring in veins and beds and in particles disseminated through the igneous and metamorphic rocks.

In addition to the magnetite, which he declared to be the predominant ore of the district, the author called attention also to

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[1]Proc. Bos. Soc. Nat. Hist. Vol IV, 1854, p. 308.

[2]First Annual Report of the Geological Survey of New Jersey for 1854. New Brunswick, 1855, pp. 28-38.

the presence of a few occurrences of hematite [limonite] in the white limestone at or near its junction with gneiss, syenite, or granite. (Pp. 37-38.)

In the following year many more details were given with respect to the occurrence of the magnetite deposits, with the special purpose of combating Rogers' theory of their igneous origin. Kitchell concluded that the deposits are sedimentary, mainly on the ground that they are associated with gneisses and granites which at the time he wrote were universally regarded as metamorphosed sediments.

In his second report[1], he described the Highlands rocks as comprising interstratified gneiss, various schists and white limestones. The limestone he considered as older than the blue Kittatinny limestone, and in this respect again differed with Rogers. All these rocks were referred to as exhibiting

"violent dislocations, being displaced vertically, laterally, contorted, folded, etc. Their general strike is northeast and southwest, and their dip southeast. They are traversed by joints * * * and in addition to their distinct stratification * * * they exhibit planes of cleavage frequently at right angles to the plane of stratification." (P. 132.)

A large number of mines were enumerated and details of their geology were given, and a summary of the occurrence of the ore was enunciated as follows:

"1. Geographically, the deposits of ore occur in a series of parallel belts crossing the Highlands, in a northeasterly and southwesterly direction.

"2. Each belt is composed of a series of deposits having the same general direction and inclination, coinciding with the strike and dip of its accompanying rocks.

"3. As a general rule each deposit is exposed at the surface only to a very limited extent, on account of its pitch beneath the rocks, towards the northeast.

"4. The outcrop of ore generally occurs on, or near, the summit of a hill or mountain ridge.

"5. The deposits are traversed by numerous joints and faults, frequently displacing portions of them to a considerable distance." (P. 235.)

No generalizations as to the origin of the ore were ventured, however, until the succeeding year, when the subject was discussed at length.

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[1] Second Annual Report on the Geological Survey of the State of New Jersey, for the year 1855. Trenton, 1856, pp. 111-248.

In the meantime Whitney[1] proposed to account for lenticular masses of magnetic ore in gneiss, like the ores of New York and New Jersey, by supposing that while they may be the result of segregation they are more likely to be

"the ruins of pre-existing igneous masses, which have been broken and worn down during the turbulent action which we may suppose to have been pre-eminently manifested during the Azoic epoch, and then swept away by currents, and deposited in the depressions of the sedimentary strata in process of formation."

In other words, he regarded them as water-born sediments, the peculiar distribution of which in long narrow bands he explained as due to transportation and deposition by currents. This view was endorsed by very few succeeding geologists, most of whom accepted Kitchell's explanation that the ores are metamorphosed sediments that were laid down in the ordinary course of sedimentation with the associated rocks and afterward folded. The long narrow deposits are, according to this view, the upturned edges of bedded rocks.

In his third report[2] this view was elaborated at some length. The ore was described as occurring in granules disseminated through the gneissoid rock as one of its components, in masses or bunches in the most highly metamorphosed rocks, which,

"with respect to their constituent minerals do not exhibit a distinct lamination nor when viewed *en masse* do they show distinct lines of stratification. Nevertheless they pass into stratified rocks like gneiss and mica schist so insensibly that no line of demarcation can be drawn between them." (P. 11.)

Finally the ores were stated to be found in seams or strata which alternate with strata of rock, and coincide with them in strike and dip. Both rocks and ore pitch downward beneath the surface toward the northeast at variable angles.

While many of the seams were said to consist of pure magnetite, most of them were described as containing in addition to the iron oxides variable proportions of apatite, hornblende, quartz, feldspar, mica and pyrite. Generally when the ore contains a considerable proportion of these minerals it is laminated with

[1] Amer. Jour. Sci. Vol. 72, p. 1856, p. 43.

[2] William Kitchell, Third Annual Report of the Geological Survey of New Jersey for the year 1856. Trenton, 1857, p. 11–13.

alternating seams of ore and silicates. When the impurities are in small quantities the ore possesses a columnar parting perpendicular to the walls of the seam.

In many instances

"large wedge-shaped masses of rock, composed of quartz, hornblende, feldspar, mica and magnetite, called by miners 'horses,' frequently occur imbedded in the ore seams. Generally a line of demarcation can be drawn between the 'horse-rock' and ore; but so insensibly do they sometimes pass into each other that it is difficult to tell where the one begins and the other ends. They vary in extent from regular seams or strata of rock alternating with the ore, to small, irregular, wedge-shaped masses, the longer axes corresponding with the strike of the strata and its lamination, which is generally perceptible, corresponding with the lamination of the adjoining rocks.

"Having described the geological occurrence of magnetic iron ore in this district, we are led to consider its origin, and to refer it to the particular class of metalliferous deposits to which it belongs, whether it is of aqueous or igneous origin, or whether it occurs in the form of stratified or unstratified deposits.

"That they cannot be referred to the unstratified deposits appears evident from the facts stated in describing the different forms in which the ore occurs; nevertheless it has been maintained by some that they are true veins of igneous origin, which implies that they extend to an indefinite length and breadth, that they differ in character from the rock in which they are situated, and have been formed subsequent to it. Such deposits do not usually coincide with the strike and dip of the strata in which they are inclosed, but generally cross the line of stratification and frequently send off branches of greater or lesser dimensions, at different angles from the main vein. The body of the vein is in most cases separated from the walls on either side by decomposed rock called selvage.

"It will be observed that none of these phenomena can be applied to the magnetic ore deposits of this district; nor can they be veins of segregation, which implies that the material of which they are composed has been eliminated or collected together from the surrounding rock by some chemical action. Such deposits are composed of a gangue, or materials different from the surrounding rock, and are very irregular in their form.

"Stratified deposits imply that they are included within sedimentary rocks, that they are of aqueous origin, and that they coincide in geological position and in the mode of formation with the rocks in which they are situated. From the facts that have already been stated, they must be referred to this class of metalliferous deposits.

"That the rocky formation of this district, including the gneiss, the hornblende, and mica schists, the magnetic iron ore, and the quartz-feldspathic rocks, are of metamorphic origin there can be but little doubt; consequently it is conceived that they were originally deposited by water in a horizontal position; that they are composed of materials derived from pre-existing rocks; and that they were subsequently disturbed in their position and altered by metamorphic agencies, which have caused them to assume their present form

and position. The origin, therefore, of these deposits of magnetic iron ore is identical and contemporaneous with the rocky strata in which they are enclosed." (Pp. 12–13.)

This opinion has been quoted at length because it is the first argument published to substantiate the very prevalent view that the New Jersey magnetites are metamorphosed sediments. Most of the geologists who have followed Kitchell have subscribed to this view and have labored to collect facts that would strengthen the argument.

In 1868 Dr. Cook[1] discussed the origin of the magnetites, repeating in the main Kitchell's description, adding a few facts and concluding with him that the ores are metamorphosed sediments. He differs from Kitchell, however, in declaring that the ore deposits never had more than a limited distribution. Because of their character he assumes that they were precipitated in lines along the banks of rivulets or the shores of quick water. He states that

"as an ore it is always found mixed with more or less rock, the rock being sometimes in grains, and at other times in large masses or in stratified streaks. The rock is the usual one of the azoic region; gneiss, syenite, hornblende, feldspar, limestone, etc., and grains of phosphate of lime are common in some of the ores. Iron pyrites are found in minute quantity in many of the ores, and in some places so much is found as to render the ore unfit for the present modes of working. In some of the ores in limestone, graphite is found.

"The ore is found in beds or layers which are conformable to the gneiss in which they lie. It is also found mixed in with the rock in all proportions, from one to one hundred per cent.; and where it is found pure, it is not uncommon to find it gradually becoming impure by the mixture of more and more rock until the ore is all gone. It is not separated from the rock by well-defined marks of division, as is the case with metallic ores in true veins, neither is there a peculiar gangue rock, such as is in true veins; but the rock is the common one of the formation. In short, everything in structure, position and attendant minerals, shows that the ore is in sedimentary beds, the same as the gneiss is. Disturbance since its original deposition has brought its beds on edge, and so far has made it like ore in veins; and having this resemblance, its beds, by the common usage of the country, are called veins, and we may so use the word in this report. There is no difficulty in conceiving of the beds as having been formed by the deposition of the peroxide of iron, and having since lost enough oxygen to change them into magnetic oxides."

[1] Geology of New Jersey. Newark, 1868, pp. 532–533.

He repeatedly states that though gneisses and white limestone are metamorphosed sediments, nowhere in the State can the slates and sandstones be shown to grade into gneisses or the blue limestone into white crystalline limestone. He declares, however, that one specimen of magnetic iron ore has been found in the Kittatinny Valley

"which is in the form of an orthoceratite, a chambered shell of the Silurian age. The specimen was about two inches long, an inch wide, and a half inch thick, and showed the markings for the chambers plainly. The form is complete and the change to magnetite is entire for all the outside of the specimen, but through the specimen there is a line of reddish-yellow peroxide of iron. Bischof, in his Chemical Geology, has long ago asserted this change to be the one by which magnetite was produced, and the specimen substantiates the possibility of such a change." (P. 332.)

"The beds of magnetic iron-ore are in layers in the strata of gneiss or limestone. They are in long narrow belts, which are parallel to the general northeast and southwest strike of the Azoic rocks. They have the appearance of having been thrown down as a chemical deposit along the borders of streams or slopes, perhaps seashores, just as oxide of iron is now deposited from spring-water when it is exposed to the air; just as bog-iron ore is now depositing in many places in Southern New Jersey, or just as oxide of iron is depositing at the salt-springs in New York and Pennsylvania. Such deposits are necessarily of limited extent. They do not spread out over a great area as deposits of sand or clay may, but are separated from the water in which the oxide of iron is dissolved by the action of air and the escape of carbonic acid, and are quietly precipitated along the banks of rivulets or the shores of larger bodies of water in which the springs enter. In the subsequent changes of level and the folding which has taken place, the axes along which the folds have been made, have been sometimes directly upon these deposits of ore, and at other times have probably been upon one side of them." (Loc. Cit., p. 332.)

In several of the mines folds are said to be developed in the ore beds, notably at the Hurdtown mine and the Durham mine, south of Easton in Pennsylvania.

From this time practically all the study of the Highland geology was confined to the geologists connected with the State Survey and their work was devoted mainly to the attempt to show some constant relation between the ore bodies and the associated rocks. Details of the geology of the iron mines were described in plenty, and many descriptions of the supposed structure of the Highlands ridges were given; but no advance was made in the discussion of the origin of ores until the advent of the members of the National Survey into the field. One or two writers

hesitated to accept the generally accredited view of the sedimentary origin of the ores and demanded some proof of its correctness. But these were isolated cases. Most of the geologists who worked in the region regarded the case as closed and the verdict as rendered the proper one.

In the report of 1872 attention was called by Smock[1] to the fact hitherto unreported, that much of the ore near Hackettstown is found as a constituent mineral of granitic and syenitic dikes. It was thought that while such rock masses may be closely related to ore beds, the probabilities of their leading to beds or veins of commercial value are not strong enough to justify much labor or expense in prospecting them. There was a marked distinction noted between this mode of occurrence and that of the regular ore beds, or veins, as the latter have definite and well-marked walls of rocks, and the ore masses conform with the rock strata.

"The dikes may be conformable to the adjacent beds, but, generally, they are not so, sometimes cutting across the strata."

In the following year Smock[2] further reported in a discussion with respect to the character of the Azoic (pre-Cambrian) rocks that the only difference between the ore and the rocks among which it is found is, that the ore beds are limited in extent, either thinning out or gradually changing in character until the ore is entirely replaced by rock,—though this may not occur in hundreds or even thousands of feet. He declared of the rocks associated with the ore, that they

"are now conceded by all geologists to be of sedimentary origin. They were originally deposited from water as sand, earth, clay, shells and corals or marl, and oxide of iron. Under the influence of pressure and heat, long continued, these deposits hardened to stone or rock. Under the prolonged and powerful influence of the same agencies the rocks were forced from their original horizontal position, turned up, bent and folded as we now find them, and changed from its earthy appearance to the crystalline structure which it now has. Examples to illustrate the possibility of these different changes might be cited, but they would hardly be in place in this report. In regard to the iron ore, however, it may be said that we have in New Jersey deposits of yellow oxide of iron now going on; that they

[1] Annual Rep. of the State Geologist of N. J. for 1872, p. 17.

[2] Ib. 1873, p. 18-19.

are in wet places, and are limited in the areas they cover. I have, in one instance at least, had a fossil from the northern part of the State of which the centre was red oxide of iron and the outer and main part was magnetic iron ore. Along our own shores, too, we are having changes of level decided enough; and we have only to imagine them continued long enough to put our present level grounds in just as inclined positions as the Azoic rocks now have."

In the succeeding year Smock[1] again recurs to the subject in a paper read before the American Institute of Mining Engineers, but adds nothing new to the discussion.

Wm. P. Blake,[2] in commenting on this paper, declared it as his opinion that the elongated form of the magnetite deposits is evidence of their detrital origin. He considered them as stream deposits that were subsequently metamorphosed.

"In a rushing current of water the heavy minerals are collected by themselves at the bottom, and the lighter ones are separated from them, a principle that is in common use for the artificial enrichment of metalliferous ores. If we imagine a rapid and narrow stream running through a country in which ferruginous rocks abounded, the iron minerals swept down the stream would be concentrated in long and irregular patches, precisely as we find existing streams sorting out the common and iron sand they carry along. These patches would naturally be connected by threads of similar ores, and the general line of the deposit would evidently be that of the river bed or current which formed them. These were probably the conditions in New Jersey. A series of rivers running down to the sea, or some great body of water in tidal current, performed the concentration in parallel lines like the streaks of iron-sand we find at this day. On the other hand, if we assume quiet deposition in previously formed valleys, we must believe the deposition to have been simultaneous throughout the whole district. How could valleys be so long and deep compared with their breadth as these beds are? They would almost be straight lines. Then, too, there must have been a constant recurrence of such valleys throughout the successive geological horizons, for Professor Smock shows that the beds are not confined to any one stratum, but are found in several and of all grades of size and richness. The evidence is that they were formed mechanically of materials swept along by currents." (Pp. 325-326).

This is a return to Whitney's view which had not been considered worthy of discussion by the New Jersey geologists because, perhaps, of the difficulty of discovering any direct evidence bearing upon it.

[1]Trans. A. I. Min. Eng. Vol. II, 1874, p. 314.

[2] Ib. p. 325.

Work on the iron ores was continued by the State Survey under Professor George H. Cook,[1] but very little was contributed in addition to what had already been learned with reference to their manner of occurrence. A few new facts, however, were reported, but they threw little light on the problem of the origin of the ores. It was pointed out that the ore veins never cut across the banding of the gneisses, and it was stated they never contain fluorite, calcite or quartz as gangue minerals. Many of the veins were described as containing wide and narrow places which pitch to the northeast, just as do the extremities of the beds. These facts were regarded as indicating that the ores are not vein deposits, but are metamorphosed sediments.

In the next year J. S. Newberry[2] added his argument to the unanimous voice of the geologists of the time. Assuming that there was no question as to the sedimentary origin of the rocks associated with the magnetites in New York and New Jersey, he thought that while the ore sheets have the aspect of veins they are much more likely to be beds deposited contemporaneously and conformably with the gneisses and which

"In the elevation and metamorphism of the mountain belt where they are found * * * have been changed to magnetites in composition and by pressure, and when softened, have been variously pinched, bunched and contorted."

A couple of years later, A. A. Julian[3] recalls the Blake view, apparently considering it a new one, to the effect that iron-ore deposits of Archean time were made mechanically, but declares that they were laid down like the accumulation of iron-sand along sea-beaches. Dr. Newberry, discussing this opinion, argued in favor of precipitation of iron oxide from its soluble salts in waters of a bog or lake receiving the drainage of a region, *i. e.*, he was inclined to favor the view of Smock. This origin, however, he seemed to apply principally to ores like those of the Lake Superior region that are associated with jasper. Professor Dana,

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[1] George H. Cook, Annual Report of the State Geologist for 1879, pp. 15, and 94–95.

[2] School of Mines Quart., November, 1880, pp. 5–6.

[3] Trans. N. Y. Ac. Sci. II, p. 6. Abst. A. J. S. (III) 25, pp. 476–7, and Phila. Ac. Science, 1882, p. 335.

in reviewing the article and the discussion, seems to regard a modification of Mr. Julian's view the correct one. He thinks the magnetites may be a beach deposit, sorted by the ebb and flow of the waters and thus concentrated on the high portions of beaches.

In 1883, the State Survey began a systematic study of the geology of the Highlands belt which was continued through several years. In the report[1] of this year the facts known about the geology of the Highland region were collected and summarized in anticipation of the detailed studies to be made later by N. L. Britton and F. J. H. Merrill. The gneisses were separated into three groups: feldspathic gneisses, hornblendic or syenitic gneisses, and micaceous gneisses. The first were reported to occur upon the flanks of the ridges and at their bases, with the hornblendic and micaceous varieties most closely associated with the ores. Magnetite was recognized as a common component of the country rock. Where it replaces the other rock components to the extent of 50 per cent. of their mass, the rock was regarded as an ore.

A comparison between the size of the ore veins and the gneiss beds of uniform composition led the author to the conclusion that "rock strata having uniform character and of equal extent cannot be said to be much more common" than the ore beds. In many of these, it is conceded, stratification is not easily recognized. Their original bedding is thought to have been obliterated by the subsequent changes to which they have been subjected.

In deference to popular usage the author concluded to use "vein" in describing the ore bodies, but the term he explains is to be understood as denoting a *bed* of ore. He referred particularly to the "pitch" of the ore bodies and stated that their prevailing strike is northeast and their pitch in the same direction, but in several of the mines the pitch is southwest and in one it is southeast. Folds are reported to exist in the gneisses associated with the ore beds and at several places in the ore beds themselves. At the Hurdtown mine the ore was described as being in a syncline pitching northeast, and a diagram is given of a section through it at the southwest opening near the turnpike (see Fig. 6, p. 138).

[1] Annual Report of the State Geologist for 1883, pp. 27–77.

The slope through which the ore was raised followed the line of the axis "and the ore appears to be a close fold and without any interbedded rock between its two legs or sides." The repetition of beds of gneisses in railroad cuts and the fact that the southeast dips of the gneiss layers are often steeper on the southeast sides of the individual gneiss ridges than on their northwest sides, were regarded as evidence that the gneisses had been folded. There was also cited, as evidence of distortion of the original beds, the presence of numerous faults or "offsets," which may run either parallel to the strike or transversely to it. In the ore beds it was noted that the faults are usually right-handed, *i. e.,* into the hanging wall, or southeast, when following the beds northeastward along their strikes. Their throw varies largely, but in most cases it is very slight. As the faults, however, are closely spaced the aggregate of the offsets is frequently great.

The ore bodies were described as being characterized by a pinch and shoot structure. The shoots were pictured as irregular lenticular bodies that lie between the rock strata, and possess with the country rock the elements of pitch and dip. Besides the walls which bound them on the dip slopes, there are also cap rocks which limit them at the top, and bottom rocks which underlie them. Sometimes the walls approach, making an arched roof or cap over the ore-body and a trough-shaped floor or bottom beneath it. The different shoots connect with each other by narrow strings or sheets of ore, which are known as pinches. A vein is, therefore, merely a succession of shoots and pinches. In many instances the pinches are caused by rolls in the foot wall of the ore-body, but sometimes both foot wall and hanging wall converge. In many instances the shoots lie one above the other in the same stratigraphic plane, and in other cases, as at the Weldon mine, they may lie side by side and parallel.

As an explanation of all these features the author makes the following statements:

"These rocks are found in beds of varying thickness and extent, and succeeding one another irregularly as newer strata or even as very recent deposits, are seen to consist of alternating series of thick and thin beds. From their composition, also, it seems highly probable that they were laid down under conditions somewhat similar to those which affect the deposition of beds of sand, clay, marl and iron ores in recent times. And there must have

been sandy, clayey, calcareous and ferruginous beds like these modern deposits in some respects. Uniform conditions may have prevailed over larger areas than they do to-day, as is proved by the extensive outcrops of rocks having the same general characters and composition. The lakes, marshes or basins in which the deposits of iron oxides or iron carbonates accumulated were of great length, and apparently of equally great breadth, and the deposition was long continued, forming thick beds, when they in turn were covered by other sediments. Thus the accumulation went on as the older strata gradually and slowly subsided until the thickness amounted to thousands of feet. The time was long, perhaps as great in length as the combined ages of all the later formations. With the subsidence of the beds, the agents, pressure, heat and water, came into action, producing the great changes wherein these fragmental sediments and fine deposits were altered into crystalline masses. This change or metamorphism of the strata was probably slow and in progress throughout a long period of time. The gradual subsidence also gave the strata more or less gentle inclination, and dip began as an element of stratification. Upheaving and compressing forces at length began their mighty work and the gently sloping beds were raised up along axial lines of great length into huge arches and depressed into deep troughs, and compressed by the powerful thrust of lateral forces into close folds so that all the beds were brought into an approximately vertical position. And from the steeper inclination of the beds on the southeast, this thrust or horizontal compression was apparently greatest on that side. As already stated, the folding took place along northeast and southwest lines, and the lateral forces pressing the strata together was from the southeast side. But it is scarcely conceivable that such prodigious energy, exerted however slowly, confined itself to the folding in one uniform direction throughout the whole area of these Archean rocks. The elevating forces may have acted very unequally and at greatly varying rate; and the inequalities thus caused, with differences in the nature of the bed and compressing forces acting with varying intensity, would tend to disturb the symmetry and produce the diverse strike and dip which we recognize as exceptional to the general course and prevailing directions. Or a combination of lateral forces would produce the twists, as it were, in the strike. * * *

"Varying intensity in the upheaval and folding forces would not only tend to produce diverse dip and strike, but also fractures and rents in the strata. The different degrees of firmness and elasticity in the strata themselves would aid in bringing out such fractures and dislocations. And faults would result from these causes. Lateral pressure exerted unequally upon a bed of uniform degree of elasticity and resistance would disrupt it along lines parallel to the line of pressure or approximately so. Pressure in the line of the strike might pucker up the beds and, sundering them, let them slip past one another." (P. 71.)

In this way a fold might be produced in a bed of iron ore accompanied by a thinning of the bed. If the squeezing process be imagined to continue until the ore is completely pinched out, an offset would be produced.

"These forces were doubtless the factors in the production of what has been styled the *shoot and pinch structure.* The ore beds possessing more elasticity than the adjacent and enclosing gnessic and syenitic rocks adapted themselves more readily to their action and accumulated in certain lines or horizons and in somewhat irregularly shaped bunches. Where the compression was less they would be thick; where more intense they would be squeezed into thin sheets, if not cut out. This pressure may have been, in part, during the deposition of the succeeding beds over the ore, and caused by their superincumbent weight, which was unequally distributed. When the effect of heat also is considered, which might result from great pressure, the causes appear adequate to the production of great inequalities in one and the same bed. But the more probable theory is that the uplifting and folding forces did more in giving shape to these ore bodies. Of course, the formation of such sediments in shallow lakelets and marshes as bog and lake ores, or the deposition of carbonate of iron in the water of lagoons, might explain the lenticular shapes of the iron ore *veins.* And the succession of shoots in the case of many of our iron mines seems to agree with the theory of such a mode of original deposition in a chain of small and partly connected bogs and lakelets. This origin determined the general direction and extent, but subsequent forces of uplifting, folding and compression must have greatly modified them and given them their present shape." (Pp. 75-76.)

In addition to the stratified rocks there are conceded to be a few exposures in the Highlands in which no clearly defined evidence of bedding can be detected. These occur often as large dikes of granite, syenite and trap. It was thought that further examination might show that some of the granites are "stratified rocks, in which the bedding has been obliterated, and the faint parallelism in the arrangement of the minerals may give the clue to the bedding."

This is the first detailed description of the ore bodies that has come down to us and the first effort to work out the structure of the region. It assumed that the entire series of rocks associated with the ores are metamorphosed sediments without any attempt to prove the assumption correct. The supposed occurrence of more schistose phases of these rocks on the flanks or ridges than along their apices was regarded as sufficient evidence of the soundness of this conclusion.

Nearly all the succeeding work in the region by the officers of the Survey tended to substantiate the views set forth in this report. A few additional facts were recorded, but nothing was discovered to cast doubt on any of these conclusions until 1889, when Nason suggested that the gneisses might be igneous in origin.

In 1884 it was found by Britton and Merrill[1] that the dips of the gneisses did not indicate their occurrence in simple folds. The micaceous and hornblende gneisses were grouped together as a single type, so that the three types of the preceding year were reduced to two. The distribution of these, however, was discovered to be so complicated that no mapping was attempted. In addition to the gneisses there was discovered also a great quantity of an unstratified gray syenite, more particularly in those portions of the district where the topography is irregular. By inference from the statements made it is plain that all the rocks were regarded as metamorphosed sediments.

In the report for 1885 Britton and Merrill[2] returned to the subject after another year's experience in the field. They grouped together all the crystalline rocks of the Highlands as Archean, but were unable to subdivide them further. They thought, however, that massive and heavily bedded granulites, quartz, syenite, etc., underlie the stratified gneisses and schists, which must be younger, but they were unable to draw exact lines between the two series.

The ores were regarded as integral parts of the stratified series. From the character of the minerals associated with them and the structure of the ore beds it is thought that there is evidence "that there has been considerable segregation accompanying the metamorphosing processes, and intense chemical action must have taken place at the time of formation of the magnetite."

Work was continued during the following year, and many details of the structure of the rocks and the ore veins were illustrated by figures and cross-sections. An attempt was made to subdivide the rocks into three series, all belonging in the Laurentian system, the sequence being (I) the massive group; (II) the magnetite-bearing group, and (III) the schistose group. The iron-bearing group was made to include the crystalline limestone, the dark gneisses and the more completely foliated gneisses generally. The divisions were said to be based on stratigraphic

[1] Annual Report of State Geologist for 1884, pp. 57–69.

[2] Annual Report of the State Geologist for 1885, pp.36–55.

evidence, but this evidence was not given. It was declared, however, that no indications of unconformities were observed, but, on the other hand, there was noted a gradual transition between the several strata. The ore deposits were declared to be limited to the second group of rocks. They were referred to as "true beds" interstratified with the gneisses. With reference to the structure of the region the authors reiterated their earlier statements that the ridges are due to folds that pitch northeast, and that the rocks are repeatedly brought to the surface by cross-faulting.[1]

In the course of the field work during 1887 a fossil plant was found in the limestone of Sussex County, supposed to be a part of the crystalline series lying along the northwest base of the Highlands. This was described[2] in the following year under the name of Archæophyton Newberryanum.

About this time there appeared the valuable report on the iron ores of the United States published by the Census office. This contained an excellent summary by B. T. Putnam[3] of the condition of iron-ore mining in New Jersey during the twelvemonth between July 1st, 1879, and June 30th, 1880. The introduction embraced an account of the geology of the ore bodies, but nothing new is ventured as to their origin. It was stated, however, that the ores are closely associated with very hornblendic phases of the gneisses.

In 1889, for the first time, doubt is thrown on the correctness of the view that all the rocks of the Highlands are metamorphosed sediments. In the report for this year F. L. Nason[4] denies the value of Britton's subdivision of the crystalline rocks into three groups. He concludes, as the result of his studies, that "the rocks of the Archean are not homogeneous, but * * * there are belts which are similar and persistent." From the distribution of the belts of graphitic rocks and of iron ores it is in-

[1] Annual Report of the State Geologist for 1886, pp. 70–112.

[2] Annual Report of the State Geologist for 1887, pp. 20–23, and Trans. N. Y. Acad. Science, Vol. VII, 1887–1888, p. 89.

[3] Report on the Mining Industries of the United States (exclusive of the precious metals). Tenth Census Report, Vol. XV, pp. 145–177.

[4] Annual Report of the State Geologist for 1889, pp. 12–65.

ferred that the entire Highland district is crossed by faults trending transversely across the ridges from northwest to southeast. The rocks are not subdivided into groups, but four rocks are defined as characteristic types, which are represented as occurring everywhere throughout the pre-Cambrian area. The first type is called the Mount Hope type. It is described as a foliated rock composed of quartz, orthoclase, plagioclase and magnetite, with the magnetite in some places replaced by hornblende or mica. The second, or Oxford type, appears to differ from the first type principally in the possession of hornblende and the absence of magnetite. In some instances biotite replaces the hornblende. The hornblende is usually distributed in strings, giving a striped appearance to outcrops. The third type, known as the Franklin type, is a thin-bedded micaceous schist, and the fourth, or Montville type, is a white crystalline limestone. The Mount Hope is thought to underlie the Oxford type, forming the summits of the hills in general with the Oxford type flanking them. A dark dioritic rock was declared to be interstratified with both of the other types.

In summarizing his studies with respect to the distribution of the types, the author says that the facts observed by him

"point most clearly to the extreme difficulty of any classification or division of the Archean in our present state of knowledge. In order to explain away these difficulties by the prevalent hypothesis of sedimentation, one must clearly prove, in the first place, that the rocks are sedimentary, and that the foliation and bedding are original and not the secondary results of metamorphic action; or, in other words, the results of pressure. * * * There is, however, another possible explanation which has gained such formidable proportions as not to be thrust aside by simple credence or non-credence. Reference is here made to the possibility that the greater part, if not the whole, of the Archean may prove after all to be eruptive, and that the schistose and foliated structure may have been caused by pressure or shearing, and that the so-called bedding planes may be due to parting planes between successive intrusive sheets." (P. 54.)

The possibility outlined by Nason has never been adequately discussed. The work of later years centered around other points in the geology of the Highlands than the origin of the magnetites, and it was not until after the United States geologists entered the field that Nason's view received much support.

In the year following his discussion of the gneisses, Nason studied the white limestone, which, following Rogers's view, he

concluded to be a phase of the Kittatinny blue limestone and therefore of Post-Archean age.[1]

With respect to the iron ores the author concludes that the mine rock is a diorite that is distinct from the country rock, which is a siliceous gneiss.

In the same year T. Sterry Hunt[2] contributed a new view to the discussion of the origin of the ores. He explained the gneisses associated with them as precipitates from the Archean ocean. The magnetites were considered in general as contemporaneous with the gneiss and as having been produced in the same way. In a few instances, however, he thought they might be vein deposits.

In the succeeding year several references were made to the New Jersey ores in the literature, but none embodied any novel views. Mr. S. F. Emmons[3] mentioned them as probably being of Algonkian age, and Messrs. Raymond and Fackenthal[4] suggested the presence of a distinct belt of titaniferous magnetite east of the main magnetite belt and passing through the Church, Naughright, Bloom and Hager mines.

The most important publication of the year was the summary of New Jersey geology made by C. R. Van Hise in connection with his review of North American pre-Cambrian geology. As the result of his investigations Van Hise[5] declared that if the white limestones are excluded from consideration,

"The evidence in favor of the detrital origin of the Highland ores is restricted to the widely disseminated graphite and to the magnetite beds of iron ore. Magnetite is widely associated with certain belts of the granite-gneisses of New Jersey, but this and its concentration in lenticular masses within the gneisses in the form of magnetite can hardly be considered as decisive evidence of their sedimentary character. The magnetites associated with the basal gabbros of the Lake Superior Keweenawan are in purely igneous rocks. The graphite of the graphitic gneiss is a point of more weight. The absence of graphite as an important constituent over large areas in any definitely-

[1] Ib. for 1890, pp. 25–50 and 51–84.

[2] Trans. Amer. Inst. Min. Engin., Vol. XIX, 1891, p. 3.

[3] Trans. Amer. Inst. Min. Engin., Vol. XXII, 1892, p. 58.

[4] Ib. Vol. XXI, 1892, pp. 275–277.

[5] Correlation Papers. Archean and Algonkian. Bulletin U. S. Geol. Survey, No. 86, 1892, pp. 414–415.

determined igneous granite-gneiss, bears in favor of the sedimentary origin of the gneissic series. If this theory proves true, the Highland gneissic series more nearly approaches the characters of a massive eruptive than any other metamorphic sedimentary rock known to the writer. Upon the whole, in the regularity of its lamination, in its lack of extreme contortion and foliation, and in the presence of graphite, the Highland gneiss is not like the fundamental complex, the genuine Archean of Canada and the West. However, there are no certain criteria upon which it can be referred either to the Algonkian or Archean. It must be simply classified, so far as present knowledge goes, as pre-Cambrian.

"If it cannot yet be decided whether the Highland gneisses are sedimentary the supposed structural divisions of Britton and Nason can be regarded as only lithological. Britton's arrangement of a massive group in the cores and schistose groups on the outer parts of the ranges can be as well explained, as has been repeatedly seen, by the eruptive theory of the origin of the series as by the sedimentary. From Nason's work it appears that certain varieties of rock have a continuous widespread distribution; but the descriptions show that his various types grade into each other instead of being sharply differentiated as supposed. Magnetite is the distinguishing characteristic of one type, and yet, in order to make out the continuity of this belt, rocks have to be classed with this type, in which hornblende and biotite are the chief basic constituents. The same thing is true of the second type, in which the hornblende, the distinguishing characteristic, is locally almost wholly replaced by magnetite or biotite." (Pp. 414-415.)

The summary of Van Hise gives a fair estimate of the condition of knowledge of the geology of the Highland rocks in the year 1891. Since this time all the work done in the region has been devoted to the study of comparatively small areas in the hope that some of the uncertainties in the problem might be cleared up.

About this time the U. S. Geological Survey entered the field, and, in co-operation with the State Survey, began the mapping of the area around Franklin Furnace and Hibernia. The first result of this work was an article by J. E. Wolff[1], in which is discussed the geological structure in the neighborhood of Hibernia. The rocks of the area are described as acid gneisses that grade into each other through variations in the proportions of their constituents, but which on the whole form well-defined beds that vary widely in thickness. All are characterized by a pitch structure due to the elongation of the mineral components and their arrangement in lines that dip northeastward. This is

[1] Annual Report of the State Geologist for 1893, pp. 359-369.

thought to be an original feature and not a structure produced by shearing, since the minerals seem to be entirely unaffected by strain, cracking or granulation. Pegmatites and dioritic gneisses are also met with, both of which are thought to be intrusive in the siliceous gneisses. All the rocks are folded into small sharp folds.

The strike of the gneisses associated with the ore bed suggests the presence of a fold,

"the center of which is about one mile due north of Hibernia, with the ore-bed, as far as now explored, lying on the eastern flank at a level several hundred feet above the lowest rocks in the center of the fold."

The rocks comprised in the fold are regarded as forming a series 3,000 feet thick. The most constant and uniform bed that could be traced on both sides of the fold consists of a fine or coarse red-weathering gneiss composed of quartz, orthoclase, plagioclase, garnet, biotite, magnetite and often graphite. This bed is supposed to lie above the ore and to be separated from it by a thickness of about 2,000 feet of rock. It is thought that the bed may represent a limestone horizon. The conclusions of the author with reference to the origin of the rocks is as follows:

"The whole series has a top and bottom, the rocks near the center of the dome having originally been below those at the periphery, so that as we go outward from the center we pass to higher levels, and moreover, the different layers of the series must have been once horizontal, or nearly so, and forced into their present position by folding, unless the common facts of stratigraphy can be set aside.

"That the foliation, in part at least, is parallel to the bounding planes of the different layers of rock (bedding), and that the pitch and foliation are closely connected, since one takes the place of the other or both occur together; also, the pitch is plainly connected with lateral compression, since it is parallel in direction and angle to the axes of crumples in the gneiss.

"That the essential crystallization of the rocks as we now find it took place either *during* or *after* the action of the compressing forces which folded the rocks and produced pitch, but not before, since the pitch-structure is inherent in the shape of the minerals as they crystallized; and that hence, if we consider the rocks to have been formed by a series of eruptive flows or segregations, one above the other, they must have been able, while in the fused state, to act as solid masses in order to form the folds which have been described—a difficult assumption.

"It is, perhaps, not possible to state definitely at present whether this original bedded series was water-deposited or clastic in the ordinary sense, or of a different nature. Facts already obtained near the Hibernia region point to

the transition of a similar garnet rock into limestone. Should this be established, it will go far towards establishing the sedimentary origin of this series, and its consequent classification as Algonkian." (Pp. 368–369.)

In 1895 a second paper[1] was presented in which Westgate classified the rocks of Jenny Jump Mountain as granitoid, biotite-hornblende gneisses, hornblende-pyroxene gneisses, biotite gneiss, hornblende-biotite gneiss and white limestone. These are cut by pegmatites, amphibolites and diabases. The gneisses occur in broad bands with a northeast strike, and in structure correspond with similar gneisses elsewhere in the Highlands. The bands themselves are banded in a smaller way, which minor banding may be the result of sedimentation, or, as seems more probable, may be a secondary structure produced by dynamic metamorphism. The pegmatite is in dikes and irregular lenticular patches in the other gneisses. The amphibolites are black hornblende-feldspar gneiss interleaved with the lighter-colored gneisses in the form of long, narrow bands. They are regarded as igneous.

The gneisses, viewed as a whole, are described as being granitoid and usually massive. There is a noticeable absence of crumpling and contortion and no well-defined schistosity in them. Their banding is uniform and constant, but no evidence was discovered that any of the light-colored gneisses are of detrital origin. Their structure was regarded as possibly secondary.

"At any rate, the mere presence of banding in the gneiss is certainly no proof, perhaps not even an indication, of sedimentary origin; for banding in gneiss has been repeatedly shown to be of secondary origin. On the other hand, the massive character which some of the granitoid gneiss assumes suggests an eruptive origin, and that a part at least of the gneiss is a metamorphosed granite." (P. 33.)

The hornblende gneisses were thought to be identical with certain black gneisses associated with the limestones, and these are regarded as intrusive. But the author does not consider it safe for this reason to conclude that all the areas of dark hornblende-gneisses are eruptive.

A study of the structure of the mountain revealed the presence

[1] Ib. for 1895, pp. 21–61.

of no folding, and none could be worked out by the study of minor puckerings, for none such exist.

The white crystaline limestones were studied in detail. They were concluded to be pre-Cambrian sediments and not metamorphosed Kittatinny limestones, as Rogers and Nason supposed. The reason for this conclusion is the uniform character of the rocks throughout their entire extent and the absence of metamorphism near their contacts with the gneisses.

Associated with the limestones, Westgate discovered a few rocks different from any that had theretofore been described from the Highlands. These are gray, banded, micaceous, graphitic and fibrolitic gneisses, and a quartz-pyroxene rock. They occur as narrow bands following the bedding of the limestones with a uniform thickness for long distances. They were regarded as metamorphosed calcareous sediments. Hornblende gneisses, amphibolites and diorites also occur with the limestones. The greater part of these, if not all, are thought to be igneous.

The third paper, published by the U. S. Geologists as the result of their work, did not appear until 1898, when J. E. Wolff and A. H. Brooks[1] again discussed the age of the white limestone. These authors proved it to be pre-Cambrian, as Kitchell, Cook and Westgate thought, and therefore not a metamorphosed phase of the Kittatinny limestone, as Rogers and Nason believed. Certain of the white gneisses that cut the limestones they decided to be intrusive.

In 1904, Peck[2] described the gneisses near Phillipsburg and the associated limestones and talc but attempted no discussion of the origin of the gneissic rocks.

In the same year A. C. Spencer,[3] in two articles, attempted the first explanation of the origin of the gneisses and the cause of their intimate association, which was based on structural evidence. His most important conclusion was that all the gneisses are igneous.

Of the three types of gneisses recognized, two were found intruding the limestone and the third, while not intrusive into the

[1] Eighteenth Ann. Rep. U. S. Geol. Survey, Pt. II, 1898, p. 425.

[2] Annual Report of the State Geologist for 1904, pp. 161–186.

[3] Ib. 247–253.

limestone, was thought to cut the other two. Pegmatite cuts all the other rocks. The magnetite was found always to be closely associated with the pegmatite. The ores occur with all types of country rock. Where limestone is the matrix the magnetite often impregnates the rock for a considerable distance from the pegmatite, though in other cases the ore is limited to the vicinity of the contact between the limestone and the dike. At all the mines the pegmatites contain magnetite as an essential component. At Edison where the ore is associated with gneisses the rock is completely penetrated by thin vein-like stringers of pegmatite. The intimate association of magnetite and pegmatite, here and elsewhere, led to the conclusion that the two are connected in origin. The pegmatites seem clearly to be invasions of material from some deep-seated source. They may have been the active agents in segregating the oxide of iron both in the dikes themselves and in the wallrocks.

In a second article Spencer[1] elaborated his conclusions and gave a few details as to the association of the different rock types. The structure of the gneisses he stated to be, in his opinion, original and their banding to be the result of fluxion. Three types of gneiss were distinguished, 1) a light-gray variety containing microcline and microperthite as the predominant feldspars, 2) a white or light-green variety composed of oligoclase, quartz and augite with only a small quantity of potassium feldspar, and 3) a black or dark-gray variety composed essentially of oligoclase and hornblende. These rocks intrude the white limestone, and are intruded by pegmatite, which is a coarse rock with a variable composition, but in which oligoclase and hornblende are very common. The magnetite was found in all the rocks, but with it was nearly always associated more or less pegmatite. The poorer ores are simply magnetite-bearing pegmatite. The richer ores contain hornblende and feldspar, and often particles of the iron oxide are completely enveloped in hornblende. From these facts the author concluded

"that the masses of hornblende and magnetite both originated as segregations connected with the invasion of the pegmatites. Instead of being bog ores or

[1] Mining Magazine, Vol. X, No. 5, 1904.

carbonates deposited in sedimentary rocks and later changed to magnetite by metamorphism, as formerly suggested, they apparently have been introduced as products of igneous activity. The process suggested, however, must not be confused with magmatic differentiation as commonly understood. * * * According to this view pegmatites are formed by the crystallization of silicate minerals from a condition which has been described as aqueo-igneous fusion or igneo-aqueous solution, it being held that all gradations from relatively dry magmas to perfect water solutions may exist, and in certain cases give rise to rocks partaking of the characteristics both of veins and of igneous dikes.

"The similarity of the hornblende and magnetite, both where they are cut by the later pegmatite and where they lie within the feldspar rock or along its walls, is evidence that the minerals in these different relations must have formed in essentially the same way.

"The process is not regarded as one of mere separation and bunching of dark silicates and magnetite within masses of crystalline rock originally containing the required elements in the necessary proportions; but it is conceived that the accretion of certain substances, such as the iron oxide, was brought about by the addition of material dissolved in magmatic waters which permeated and moved through the pasty pegmatites as long as they were in an unconsolidated condition. These waters are also appealed to in explanation of deposits in limestones where there is no actual contact with pegmatite masses, and it may be that they have caused a replacement of calcite by metasomasis."

A few years later W. S. Bayley,[1] in a description of the geology of the Highlands portion of the Passaic quadrangle, also concluded that the greater portion of the gneisses are igneous. These were supposed to be intrusive into a pre-existing series of old rocks which are now represented by the white (Franklin) limestone, a few quartzites, conglomerates and micaceous schists and a series of black gneisses, which may be metamorphosed tuffs or clayey sediments. The age of these is regarded as Grenville (Algonkian). Subsequent pegmatites cut igneous and sedimentary rocks alike, and finally the whole complex was cut by Newark diabase dikes.

The ores were found to be associated in part with pegmatites, in part with limestone, and in part with gneisses. Those associated with the pegmatites were considered as an essential part of this rock, and, therefore, as intrusive. The origin of the remaining ores is left in some doubt. They are neither igneous in the sense used by Rogers nor metamorphosed sediments in the sense

[1] Folio 157, U. S. Geol. Survey, pp. 24 and 25; Folio No. 1, Geologic Atlas of N. J., pp. 24 and 25.

in which this term is employed by Kitchell. Some of their material may have been incorporated with the sedimentary material that yielded the black gneisses, but in their present condition the ore bodies are believed to have been introduced in part, at least, by "hot circulating solutions under conditions of igneous metamorphism." Subsequent to its formation, however, the ore is thought to have been able to move as a mass and to a moderate extent to invade the surrounding rocks in the form of small dikes or veins.

A. C. Spencer[1] becomes a little more definite in his discussion of the magnetites of the Franklin Furnace area. He ascribes the gneisses to "the solidification of silicate magmas of deep-seated origin," but declares that these magmas may have

"derived from the deep portion of the lithosphere dissolved and incorporated portions of the previously solid rock into which they were injected. * * *

"It is possible that the magmas or silicate solutions contained considerable water, and that cooling and decrease of pressure led to the beginning of solidification by the separation of the least soluble constituents through crystallization. Once divided into solid and fluid portions, separation of these phases might ensue, and such separations would amount to differentiation of the original magmas. It is believed that in some such way, and possibly also by the absorption of older rocks, all the varieties of the Losee and Byram gneisses may have originated. This differentiation hypothesis provides also for the production of metamorphism in the Pochuck gneiss and the Franklin limestone and suggests a method by which the notable deposits of iron and zinc ore may have been segregated. Hot mineral-bearing waters expelled from the magmas during the progress of crystallization would have been able to produce the observed metamorphism and the ore deposits.

"The foregoing considerations are recognized as, for the most part, highly speculative, and in reality the history of pre-Cambrian time is very obscure. What may be confidently stated is that all the rocks of the ancient complex reached their present state of crystallinity together, during a period in which materials were being transferred from the deep earth toward the surface; that an unmeasurably long period elapsed before the oldest Paleozoic rocks were laid down; that during this interval deep erosion ensued; and that when the Paleozoic seas advanced over the region it had been reduced to an almost featureless plain. It is probable that the interval between the original deposition of the Franklin limestone and the deposition of the Hardyston quartzite was longer than the sum of all the subsequent periods."

With reference to the ores Spencer[2] remarks that their origin

[1] Folio No. 161, U. S. Geol. Survey, 1908, p. 19; Folio No. 2, Geol. Atlas of N. J., 1908, p. 19.

[2] Folio 161, U. S. Geol. Survey, 1908, p. 8; Folio 2, Geologic Atlas of New Jersey, 1908, p. 8.

is obscure. Since they offer in themselves no adequate clues for determining their origin,

"the best that can be done in this direction is to assign the deposits to the most probable place in the geologic history of the pre-Cambrian rocks. * * *

"The magnetite ores * * * are believed to have been formed by igneous processes connected with the invasion of the region by the granitoid rocks which are characteristic of the pre-Cambrian area."

In some of the mines, as at Andover, it appears probable that the ore was deposited from solutions as replacements of limestone, shale, etc. Elsewhere, more particularly where the ore is in the gneisses, the magnetite appears to have had a magmatic derivation.

"Some of the ore-bodies may be essentially masses of igneous rock which acquired the characteristic tabular form during the general migration of the deep-seated magmas that gave rise to the gneisses of the region; others may represent shreds of limestone or other rock, older than the igneous gneisses, that were soaked and altered by solutions emanating from the invading magmas."

The existence of magnetite-bearing pegmatite is considered corroborative evidence of the correctness of the view that the source of the iron was deep-seated and that its concentration occurred through igneous or magmatic agencies.

Leith[1], in his classification of the iron ores of Canada, places the New Jersey magnetites, or at least some of them, in his "pegmatite type," defining this as ores extruded from magmas after their greater portions have partially cooled and crystallized. "They are deposits from essentially aqueous solutions mixed in varying proportions with solutions of quartz and the silicates." To this class, among other types of ores, are assigned those along the contacts of limestone and igneous rocks.

Section III.

SUMMARY OF CONCLUSIONS REACHED BY STUDIES OF MAGNETITE DEPOSITS IN OTHER DISTRICTS.

Though much of the work that has been done in this country upon the magnetite ores has been in connection with those of the Highlands in New Jersey and New York, not a little energy

[1] Economic Geology, Vol. III, 1908, pp. 276–291.

has been expended in the attempt to learn something definite about the origin of this class of ores in other portions of the United States. The magnetites of the Adirondacks have been studied assiduously by Kemp, Cushing, C. H. Smyth and Newland, but the conclusions reached by these geologists is not much more definite than those reached by the students of the New Jersey ores.

The rocks of the Adirondacks are very similar to those of the Highlands, with the addition of gabbros and anorthosites as late intrusives and a comparatively large development of schists that are believed to be metamorphosed sediments. These are usually associated with white limestones. Kemp[1] regards the ore body at the Hale mine as a part of the white limestone that is rich in magnetites.

C. H. Smyth[2] declares that the pre-Cambrian limestones of the northern Adirondacks are interbedded with micaceous and garnetiferous gneisses, and with pyroxenic and hornblendic gneisses, some of which have the appearance of interbedded members of a sedimentary series, while others closely resemble intrusive rocks. The latter are much mashed, thus being unlike the corresponding New Jersey rocks. Between the areas of the limestone-gneiss series are other areas in which the rocks are mainly very massive gneisses that are thought to be, at least in part, of igneous origin. Cutting all these rocks are distinctly intrusive mica granites, diorites, gabbros and diabases.

Among the phases of the gabbro is described an augite syenite, closely resembling the Byram gneiss of New Jersey. Many of the more massive gneisses are also regarded as phases of the gabbros.

Later H. C. Cushing[3] also described the augite syenite from another portion of the Adirondacks, and, like Smyth, considered it a phase of the gabbro.

As work in the region continued larger areas were surveyed, attention being devoted mainly to the distribution of the gneisses.

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[1] Bull. Geol. Soc. of America, Vol. 6, 1895, pp. 241–262.

[2] Ib. p. 263.

[3] Bull. Geol. Soc. of America, Vol. 10, p. 77.

As in the case of the corresponding New Jersey rocks, this later work tended toward the conclusion that the gneisses are igneous, and that their association with the ores cannot be considered as lending credence to the view that the latter are members of a sedimentary series contemporaneous with a set of siliceous sediments which later by metamorphic processes gave rise to the gneisses.

In 1900 Kemp,[1] Cushing[2] and Smyth[3] all mapped large areas of the Adirondacks finding exactly the same conditions prevailing over the country studied at this time as were observed over other portions of the area in 1895. Smyth declares that the gneiss series is a complex, but he groups all of the gneisses together because the difference in the ages of the different units is comparatively slight, and because all are believed to have originated in a common source. Some of them are intrusive in the limestone and are therefore known to be igneous. Some of the gneisses also enclose fragments of schist that often appear as dark bands in the lighter rock.

A further contribution was made in the succeeding year by Cushing[4] in the statement that the syenite cuts the anorthosite and is cut by granite. Since, on the other hand, it grades both into the anorthosite and the granite, the author considers all three rocks as differentiates of a single magma and as younger than the sedimentary Grenville rocks. The succession in the district is thought to be as follows: 1) a great group of gneisses, in part probably igneous; 2) a series of crystalline limestones and quartz, sillimanite and graphite gneisses, believed to be metamorphosed sediments (the Grenville series), interbanded with dark basic gneisses that are probably igneous, and 3) intrusive anorthosites, granites and syenites.

In a later publication[5] he groups a number of the gneisses

[1] Fifty-third Ann. Rep. N. Y. State Museum for 1899 (dated Dec., 1900), r. pp. 20–35.

[2] Ib. r. pp. 36–82.

[3] Ib. r. pp. 83–104.

[4] Fifty-fourth Ann. Rep. N. Y. State Museum for 1900 (Dated 1902), Vol. 1, r. p. 23.

[5] Bull. 95, N. Y. State Museum, 1905.

under the name of the Saranac formation, which is regarded as younger than the Grenville series and as igneous in origin.

The magnetite deposits, according to Kemp,[1] occur in microperthitic and pyroxene gneisses of this formation, 1) on the contact between these gneisses and the gabbros, 2) on the contact between gabbros and the gneisses involved with the crystalline limestone (presumably sedimentary gneisses), 3) and, finally, within the limestones near gabbro intrusions. The relations of the ore bodies to the surrounding rocks are the same as in New Jersey. With reference to their origin the author remarks that many geologists have regarded the magnetites associated with the pre-Cambrian gneisses

"as segregated veins whose iron-oxide was collected by a leaching of the neighboring wallrock and a concentration of it into lenticular masses parallel to the foliation (or supposed bedding) of the gneisses. It is, however, difficult to conceive of the ores coming through hard crystalline rocks in this way (unless the deposits were formed before metamorphism) and of making a place for themselves by either forcing the wallrock to bulge laterally or by replacing it. If deposition before metamorphism is assumed, we are then brought back to the uncertain ground of what the rocks were in those early times. The lenticular shape is best accounted for by pressure and consequent stretching of a bed or mass already formed, and for magnetites not associated with rocks demonstrably igneous, the above conception of a segregated vein may properly seem reasonable.[2]

"Others have thought them replacements of limestones, presumably stretched out into lenticular beds by dynamic metamorphism; but these magnetite mines are notably lacking in minerals involving much lime; and calcite, while occasionally met in small cross-fissures, is, as a rule, a rarity.[3] Its original existence is a matter of assumption.

"Again, conceiving of the gneisses as originally fragmental sediments, the magnetites and their associated apatite have been regarded as concentrated placers or shore-deposits of relatively heavy minerals, such as we sometimes see along large rivers or on sea-beaches.[4] This view has claims to serious attention; but, again, it is built on the uncertain foundation of the early history of the gneisses. * * *

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[1] Trans. Amer. Inst. Mining Engin., Vol. 27, 1898, pp. 146–203.

[2] Compare R. S. Tarr, "Economic Geology of the United States," p. 130.

[3] See, in this connection, J. P. Kimball's "Genesis of Iron-Ores by Isomorphous and Pseudomorphous Replacement of Limestone, Amer. Jour. Sci., Sept., 1891, 231; Amer. Geologist, Dec., 1891, 352. Archean magnetites are not specifically treated.

[4] This conception is urged by B. J. Harrington, Can. Geol. Survey, 1873–74, p. 193, and by A. A. Julien, Proc. Philadelphia Acad. Sci., 1882, p. 335.

"It is to be remembered that [in dealing with the magnetite deposits,] we have to deal with long, irregular bodies of magnetite, at times in double or triple beds, or chutes, with much pegmatite associated, that itself contains large crystalline masses of magnetite. Traces of titanic acid have been met in all the mines; but it is in very small quantity and may be largely in the form of dissemination of titanite, a mineral that is common in the associated wallrock. On the analogy of the neighboring titaniferous ores that occur in gabbro and that are unquestionably of igneous origin, *i. e.*, by the crystallization and concentration of titaniferous magnetite in a fused and cooling magna—one might infer the same for these, lying, as they do, along the outer portions of a gabbro intrusion." (Pp. 191–192.)

To the author it seemed most reasonable to regard the ores near Port Henry, N. Y., which are near contacts between gneisses and the intrusive gabbro

"as contact-deposits formed by the influence and stimulus of the gabbro intrusion; but, at the same time, the difficulties and uncertainties are appreciated, and the conception is supported as the *most reasonable* one, rather than as one absolutely demonstrated. Their history would then be somewhat as follows: In pre-Cambrian time, and before the complete metamorphism of the gneisses from their original conditions, whatever they were, and while the rocks were deep-seated, the intrusion or intrusions of the gabbro took place. Attendant on their cooling and crystallization, the omission of highly-heated solutions of iron and other compounds transpired, presumably with vapors in some degree, and these circulating along the various contacts gave rise to the ore-bodies. They must have replaced in large part the wallrocks and have made a place for the iron-oxide in this way." (P. 193.)

At the same time great masses of pegmatites came into existence.

"Iron ores themselves have been referred to contact action in Norway, and on looking the subject up, the writer discovered that the same view had been taken some time ago by Prof. Vogt[1] for certain ores in Norway that are generally associated with granite. * * * Professor Vogt even goes so far as to refer to the igneous intrusions the formation of veins as much as 1.5 kilometers distant, but while one might hesitate about such remote instances as these, greater confidence may be felt regarding those at or very near the contact. As investigation of the geology of the Adirondacks progresses, it is more and more evident that the parallelism with that of Scandanavia is in many ways very close." (P. 194.)

Very recently D. H. Newland[2] has summarized his views on the geology of the Adirondacks in a paper in which he described

[1] J. H. L. Vogt, On Dannelse af jernmalmforekomster, especially Part II, Jernmalmvorkomster dannede ved pneumatolytiske processer. ("On the Formation of Iron-Ore Bodies." Part II, Iron-Ore Bodies formed by Pneumatolytic processes.) Norges Geologiske Undersögelse. Kristiania, 1892.

[2] Economic Geology, Vol. II, 1907, p. 763–773.

the rocks of the region as a series of limestones, gneisses, schists and quartzites which he correlates with the Grenville series of Canada. These rocks are cut by anorthosite, gabbro, syenite resembling the Byram gneiss of New Jersey, granite, various gneisses derived from the more massive rocks and a group of gneisses of doubtful origin that are tentatively placed in Cushing's Saranac formation. The ores as described are like those of New Jersey in composition and in their associations. In form the ore-bodies are also in general similar to those in New Jersey except in the eastern portion of the area where they

"often exhibit a complexity of pinches, swells and compressed folds that afford puzzling structural problems." "These forms are believed to be conditioned by the structures of the enclosing rocks, and therefore it is inferred that the ores 'must have been deposited before the regional metamorphism took place, or at least before the rocks received their present structural arrangement. They have passed through all the vicissitudes of squeezing and deformation impressed upon the walls.'"

Attention is called to the fact that there is no uniform association of ore and country rock—that the ore may occur with walls of any of the rocks in the region except the most basic ones, and that in some cases the ore is nothing but country rock impregnated with magnetite.

The ores are supposed to have originated within the wall rocks, mainly by magmatic differentiation. Gaseous and water circulations set up by the cooling magmas are thought to have helped to assemble some of the ore-bodies. The titaniferous magnetites associated with the gabbro of the region are considered by all geologists as segregations from the gabbro magma. The acid magmas constituting the gneisses are known to grade into one another, and, consequently, are conceived as being differentiates of a single magma. There is as much iron in the gneisses as in the gabbros, and there is titanium in both rocks. In the gneisses, which are the most acid rocks, the titanium combined partly with calcium and silica, forming sphene, while in the gabbros with a deficiency in silica the titanium combined with iron in the magnetite.

Where the ore bodies are in the Grenville gneisses and schists, the ore is apt to be highly pyritiferous, the pyrite having origin-

ated, probably, in organic matter in the sedimentary rocks from which the schists were made.

No explanation of the method of origin of these ores is proposed. The author thinks the evidence in favor of their sedimentary origin is not strong. He believes, however, that they may have been

"formed before the surrounding rocks had undergone their final compression and folding, because they have laminated textures and conform in their arrangement to the general field structures.

"Their introduction may thus have taken place before the period of general metamorphism, in which case it might have been accomplished by underground circulations, with limonite or carbonate replacing the original shales and limestones as the first step."

The presence of organic matter in the beds, which is suggested by their content of graphite, would tend to the production of magnetite rather than hematite.

In a later paper the author[1] describes in detail the mines of the Adirondacks, and discusses the origin of the ores in practically the same words as are used in his preliminary paper, and finally Koeberlin,[2] in discussing the origin of the Tilly Foster and the Croton ore bodies in the Brewster district, New York, ascribes both to magmatic agencies. The Tilly Foster ore is thought to be the result of the action of solutions and vapors upon a body of limestone, and the Croton ore body to be the result of the segregation of magnetite within a sill of syenite intruded into schists.

Magnetite ores in old crystalline rocks have been studied in several other portions of North America, but in most cases there is more or less doubt expressed as to their origin. Those of Eastern Ontario are described by F. J. Pope[3] as occurring in Laurentian gneisses and Grenville schists and limestones. The ore bodies are lenses and impregnations in the schists and gneisses and in crystalline limestones at their contacts with the schistose rocks, which are regarded as metamorphosed sediments. The ores grade into these. In some places the schists immedi-

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[1] Bull. 119, N. Y. State Museum, Albany, 1908.

[2] Economic Geol. Vol. IV., p. 713-754.

[3] Trans. Amer. Inst. Min. Eng., Vol. 29, p. 372.

ately contiguous to the ores are acid gneisses containing bands of black schist and in other places are hornblende schists which are thought to be metamorphosed diorites or diabases. The ore bodies in the schists are composed of aggregates of magnetite, hornblende, pyroxene and garnet with fluorspar, quartz and uraninite present in a few cases. Those in the limestone consist of hornblende and augite with some serpentine and epidote.

In North Carolina the conditions appear to be somewhat similar in general but to differ in detail from those in New Jersey. Arthur Keith[1] describes the ores as occurring in pods in a granite-gneiss. These lie parallel to the schistosity of the gneiss as great lenses dipping to the southwest. The magnetite is associated with a gangue composed of hornblende, pyroxene, epidote, a little feldspar and quartz.

The ore bodies were deposited much later than the production of the schistosity in the enclosing gneiss. It is inferred by the author that they were not due to original segregations from the granite, but that they were secondary phenomena. They are regarded as replacements of granite, through the action of circulating water charged with mineralizing agents. This dissolved the rock and perhaps added to the rock minerals and re-deposited the material in favorable situations. While the deposits have not the shapes of veins, their occurrence was controlled by the schistosity of the granite. It is thought that the mineralizing solutions were put into action by the great masses of gabbro that lie at some little distance from them, though in some places there are no igneous rocks in the vicinity of the ores that can be appealed to as sources of such solutions.

The magnetites of Utah are believed by E. P. Jennings[2] to be igneous intrusions that were differentiated from a subterranean basic source. Leith and Harder[3], on the contrary, explain the Utah ores as the result mainly of contact action upon limestone.

These ores are on the contacts of limestone with andesites occurring as laccolites. From the relation of the magnetite to the

[1] Bull. No. 213, U. S. Geol. Survey, 1903, p. 243.

[2] Trans. Amer. Inst. Min. Eng., Vol. 35, p. 338–346.

[3] Bull. No. 338, U. S. Geol. Survey, p. 75–86.

limestone and the andesite, the character of the minerals associated with it in the ores, and the manner of occurrence of the latter it is shown very clearly by these two geologists that the origin of the ore must be ascribed to hot solutions

"rising from a deep-seated source through fissures in the andesite now filled with ore, at a period closely following the crystallization of at least the outer part of the laccolitic mass." (P. 76.)

The principal source of the solutions is thought to have been the hot andesite magma, and the solutions themselves are inferred to have been above the critical temperature of water (365°). The ores were further concentrated by hot solutions flowing from lavas that were laid down upon the ores and associated rocks. These introduced new minerals into cavities in the ores, adding small quantities of iron compounds, among other things, to the aggregate of magnetite and silicates already existing. Weathering processes have also modified the ores but resulting enrichment has been almost nil.

The famous magnetite deposits at Cornwall and at other points in Berks and Lebanon counties, Pennsylvania, are considered by A. C. Spencer[1] to have a similar origin. These ores are at the contacts of Paleozoic shales and limestones with intruded diabases. The ore-masses are regarded as the result of contact metamorphism. The theory of their origin

"is that the magnetite ore-bodies of the Cornwall type have been formed by the more or less complete metasomatic replacement of sedimentary rocks, mainly limestones and limy shales, by iron minerals precipitated from percolating heated solutions set into circulation by invading diabase." (P.187.)

Over sixteen years ago Vogt reached practically the same conclusion with respect to the magnetites of Norway (see p. 186). Trüstedt[2] considers the similar ores of Pitkäranta, Finland, as partly replacements of limestone at the contact of granite intrusions, produced by solutions emanating from the granite magma, and partly as direct precipitates from these solutions; and finally

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[1] Bull. No. 315, U. S. Geol. Survey, p. 185–189.

[2] Otto Trüstedt: Die Erzlagerstätten von Pitkäranta am Ladogo. See Bull. No. 19, Com. Geol. de Finlande, 1907. Abstract in Economic Geol., Vol. III, No. 6, p. 540.

Stutzer,[1] in discussing the magnetites in the pre-Cambrian rocks of Lapland, assigns to them a magmatic origin, believing them to be differentiates of the magmas which produced acid porphyritic rocks with which they are associated. In certain of the districts described the ores are associated with gneisses which are in many respects almost identical with the gneisses associated with the ores in New Jersey.

In summarizing the discussion on the origin of the magnetic ores, J. F. Kemp[2] enumerates the following theories that have been proposed from time to time to explain them. No one is favored by the author to the exclusion of the others. The reader is left to take his choice.

1. Intruded (eruptive) masses. This theory supposes that the lenses have been intruded like trap dikes, and have been squeezed and pinched apart. Though formerly much advocated, it is now generally rejected.

2. Excessively basic portions of igneous rocks. This supposes that large amounts of iron oxide have separated in the cooling and crystallizing of basic magmas. There are such occurrences, although seldom, if ever, pure enough or abundant enough for mining. The titaniferous magnetite of the Minnesota gabbros is of this class, and also the Brazilian ore and the Cumberland Hill (R. I.) peridotite ore. Should such igneous rocks be subjected to regional metamorphism and the stretching action characteristic of it, the ore masses might be drawn out into lenses.

3. Metamorphosed limonite beds. This idea has been most widely accepted in the past for the New Jersey deposits. It pre-supposes the existence of limonite beds which became buried and subjected to metamorphism, changing the ore to magnetite, and the walls to schists and gneisses. Igneous rocks have apparently changed limonites to magnetites at Cornwall, Pa., and in Utah, but such changes by regional metamorphism are less easy to demonstrate.

4. Replaced limestone beds, or siderite beds subsequently metamorphosed as in the Lake Superior region. Such deposits may pass through a limonite stage, and after metamorphism may become magnetite.

5. Submarine chemical precipitates.

6. Beach sands. According to this theory the lenses are regarded as having been formed as beaches along a shore. The same heavy minerals sometimes occur with magnetic lenses as are found on beaches.[3]

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[1] O. Stutzer: The Geology and Origin of the Lapland Iron Ores. Neues Jahrbuch für Mineralogy, etc., B. B. XXIV, 1907, and Journal of the Iron and Steel Institute, No. 2, 1907. Abstract in Economic Geo., Vol. III, No. 6, p. 545.

[2] The Ore-deposits of the United States and Canada. N. Y., 1905, pp. 181–183.

[3] See B. J. Harrington, Can. Geol. Survey, 1873, 193; A. A. Julian, Phila. Acad. Sci., 1882, 335.

7. River bars. This regards the lenses as due to the concentration of magnetite sands in rivers or flowing currents. Hence the overlapping lenses, the arrangement in ranges or on lines of drainage, and the occasional swirling curves found on the feathering edges of lenses, as in the Dickerson mine, Ferromont, N. J.[1] It is also reasonable to suppose that lakes or still bodies of water may have occurred along such rivers and have occasioned the accumulation.

8. Segregated veins. By this method the iron oxide is conceived to be concentrated by slow segregation in solution from a state of dissemination in the walls to form the ore bodies along favorable beds. The action is analogous to the formation of concretions, and is illustrated on a small scale by the well-known disks of pyrite, or of siderite, that form in clays and shales.[2] It is a curious fact, however, that some magnetites are in wallrock that hardly shows a trace of a dark silicate.

The lenses at Hammondville, in the Lake Champlain district, are in a white or light-colored gneissoid rock, consisting of quartz, acidic plagioclase, and a few scattered garnets. In such surroundings segregation could not be applied, but where the walls are supplied with hornblende and other ferruginous minerals, and are reasonably basic, it might be advocated.

It will be noticed from this summary that as late as 1905 the views held concerning the origin of the magnetic ores were almost as numerous as the geologists who had studied them. The majority explained the ores as originally sediments. One theory accounted for them as of vein origin, but the process by which they were formed was supposed to be secretion from waters that percolated through the wall rocks, dissolving from these their iron compounds and depositing iron oxide in favorable situations along selected beds. Within the past few years, however, as more detailed work has been done, the various views of different students have become less divergent. The sedimentary theory has been abandoned and practically all of those who have studied the magnetic deposits in gneisses, whether in Finland, Lapland, Pennsylvania, Utah, New York or New Jersey, have reached approximately the same conclusion—that the magnetites are the result of magmatic emanations; that is, that the source of their material was the iron in cooling igneous magmas, and that their deposition in their present situations was largely the result of upward flowing hot waters. This was accompanied in some places by intrusions of iron-bearing silicate

[1] See H. S. Munroe, School of Mines Quarterly, Vol. III, p. 43.

[2] See, also, Dakyns and Teall, Quar. Jour. Geol. Soc. LXVIII, p. 118.

magmas, but much of the iron was transported in hot solutions. The deposits are veins in the sense that their material was deposited from water, but this water was of magmatic and not of meteoric origin, and the source of the iron was beneath the rocks enclosing the ore-bodies, and not in them. They may be called, in short, igneous veins.

CHAPTER IX.

ORE RESERVES AND EXPLORATION.

CONTENTS.

RESERVE.

It is impossible to estimate with even approximate correctness the quantity of available magnetite still in the ground in the Highlands of the State. If the theory of origin of the New Jersey magnetites is correct, there is no reason to suspect that the ore bodies do not extend to considerable depths. The depth already reached by some of the mines without noticeable change in the character of the ore encountered, is corroborative evidence of the correctness of the inference that there is nothing inherent in the nature of the ores, or their method of origin that would limit them below. A few of the mines that had reached considerable depths have been abandoned because the ore became lean, or wedged out, but this is interpreted as meaning that a pinch in the vein had been reached in the course of mining, that the lean rock underlying the ore lenses had been penetrated, and that the expense of the dead work required to develop new lenses was so great that at the current price of ore it was not thought advisable to undertake the explorations necessary for this purpose. In several instances, where mines had been abandoned because of lack of ore, later explorations succeeded in locating new ore bodies, and the mines again became active. In the few other cases where mines were closed permanently the ore was lost by faulting.

In most cases of closed mines operations ceased because the price of ore fell below the cost of mining and transportation. The ore was comparatively lean, it was in small bodies, and was so far from railroads that the charges for cartage became prohibitive. With an increase in the price of ore it is quite certain that some of these idle mines will again become productive. The number will be further increased when better transportation facilities are supplied. The greatest incentive to increased production, however, will come when the consolidation of small properties shall make it practicable to erect magnetic cobbers to separate the ore from the useless material. Much of the ore as it is raised from the mines is too lean to work profitably, even under the most favorable conditions, so long as the price of iron remains near the present figure. With a small amount of concentration much of this ore would be available for use even at the present prices of the metal. With a very little increase in price the quantity of ore that might be raised and concentrated would be greatly increased.

At several of the now abandoned mines efforts were made from time to time to increase the metallic content of the ores by some method of concentration, but except under very favorable conditions the projects have not been successful from a commercial standpoint. Statements of the results of experimental runs have not been published except in the case of the Beach Glen mine, so that we have little data upon which to base opinions as to the conditions under which such concentration of lean ores might become profitable. At the Beach Glen mine, in 1899, crude ore to the amount of 900 tons yielded by magnetic concentration 400 tons of a 60 per cent. ore, containing .009 per cent. of phosphorus, and in the following year 16,845 tons of rock containing 30 to 40 per cent. of iron gave 6,479 tons of ore with an iron content of 60 per cent.

In estimating the amount of reserve ore it must be remembered that only those ore bodies have been exploited that outcropped, or that are continuations of those that outcropped. From the general character of the distribution of the ore lenses in the veins it is probable that the present land surface must in many places pass through pinches between the ore lenses. If

this is so there must be ore bodies just below the surface which, because they do not outcrop, have not yet been discovered. How many of such ore bodies may exist within working distance of the surface there is no means of knowing without actual exploration. There are many magnetic lines running for longer or shorter distances in the direction of the prevalent strike of the veins, and these are supposed to indicate the presence of magnetite at no great depth under the surface. Many of these lines have been explored, and in some cases ore bodies have been disclosed where there was no visible evidence of their existence on the surface, but in most cases the explorations have lacked thoroughness and have been abandoned before satisfactory results were reached. It is morally certain that a thorough investigation of some of the other lines would also disclose the presence of ore bodies where they are not now known to occur. Whether these would prove as valuable as those that have been worked cannot be foretold, but from the strength of the attraction on some of the lines, their continuity, and the breadth of the magnetic zones, it is probable that some of these hidden ore bodies are of generous proportions. The most systematic work that has ever been done in the State along these lines is that which was undertaken under the direction of Mr. Thos. A. Edison about fourteen or fifteen years ago. Before locating the concentrating works, which were later built at Edison, a thorough magnetic survey of the most promising ore-producing districts of the Highlands was made, and the results of the work were plotted in a series of maps, on which the lines of maximum dip were indicated.

An inspection of these maps shows that the areas over which high dips have been observed are in the aggregate very large, thus indicating a considerable reserve of ore which has not yet been touched.

The total yield of ore from the State during the past hundred years or more (to the end of 1907) is estimated at about 22,522,000 tons (practically all magnetite), the largest production being in 1882, when nearly 1,000,000 tons were raised. Of this aggregate the Hibernia mines have yielded about 5,000,000 tons, the Richard mine 3,000,000 tons, and the Mount Hope and Hickory Hill mines about an equal amount. That there is at

least as much ore within reach in these mines under present mining conditions as has already been taken out, no one who is acquainted with them will doubt. Besides, there are still large reserves of good ore known to exist in the Oxford Furnace group of mines, in the Hurd, Huff and Orchard mines at Wharton, in the Ford group of mines northeast of Lake Hopatcong, in the mines at Ringwood, and in the Ahles mine near Pequest Furnace. In addition there is a large quantity of ore in many abandoned workings scattered throughout the Highlands that awaits only slight concentration and cheap transportation to make it available for use, and an unknown but probably large quantity of ore that is equally as good as that now being mined. A very conservative estimate of the quantity of good ore still capable of being mined from the deposits already known in the New Jersey Highlands is 35,000,000 tons.

If we add to the quantity of fairly high-grade ore still remaining in the active and abandoned mines of the State the quantity of magnetite in the lean ores—ores that have never been mined and can never be of value without concentration—the amount of material that might be used for the manufacture of iron under favorable conditions will be greatly augmented. We may get some idea of the magnitude of the quantity when we recall that a plant with a concentrating capacity of 700,000 tons annually was recently constructed at the site of the old Ogden mines. That this plant was not a commercial success does not invalidate the conclusion that a vast quantity of lean ore exists in the New Jersey hills, and that it can be profitably extracted under favorable conditions. With a comparatively slight increase in the value of ore and a modification in the method of treating the crude material the plant in question might have been successful. In any event the calculations that were so carefully made before the concentrator was built indicated that a sufficient supply of crude material was available to warrant the construction of a plant of enormous capacity.

The figures upon which these calculations were based are not now available, but a rough estimate of the amount of magnetite in the vicinity may be based on what can be seen. The surface has been stripped around the old mine sites over an area measur-

ing about 5,000 feet in length and 200 feet in width, showing magnetitic gneisses that are pretty uniformly penetrated by magnetite-bearing pegmatites. The percentage of iron in the rock as a whole can, of course, not be estimated accurately. If, however, it be assumed that the magnetite content is uniformly 12 per cent. of the rock as it might be quarried, *i. e.,* taking everything, and that the specific gravity is 3, which is extremely low, the total tonnage of 72 per cent. ore in the rock above 500 feet in depth is about 7,500,000[1]. But the width of ore-bearing rock is known to be much greater than 200 feet. It is probably at least three times as great. Moreover, since the strong line of magnetic attraction that runs through the stripped area extends for a distance of 4 miles or more it is probable that the quantity of lean ore contributory to the concentrating plant is 7 or 8 times as great as the estimate given.

Equally productive areas probably occur in the neighborhood of the Dickerson, Oxford, Ringwood, Rutherford, Byram, Allen, Scrub Oak, Mount Olive and perhaps some other mines. If, therefore, the quantity of ore that may be obtained under favorable conditions in the Ogden mine area is properly estimated in the millions of tons, the total quantity of ore available under similar conditions from the entire Highlands must be estimated in the hundreds of millions. Very little of this is capable of being utilized at present, but in the future when the richer ores of the country shall have been exhausted, the New Jersey lean ores will afford a source of material which will be available to the furnaces in the State and furnish them with a source of metal for many years.

EXPLORATION.

There are no means now known by which the positions of ore bodies beneath the surface in the Highlands may be predicted from the geological features observed above ground. It is known that the best and most persistent veins are associated with dark

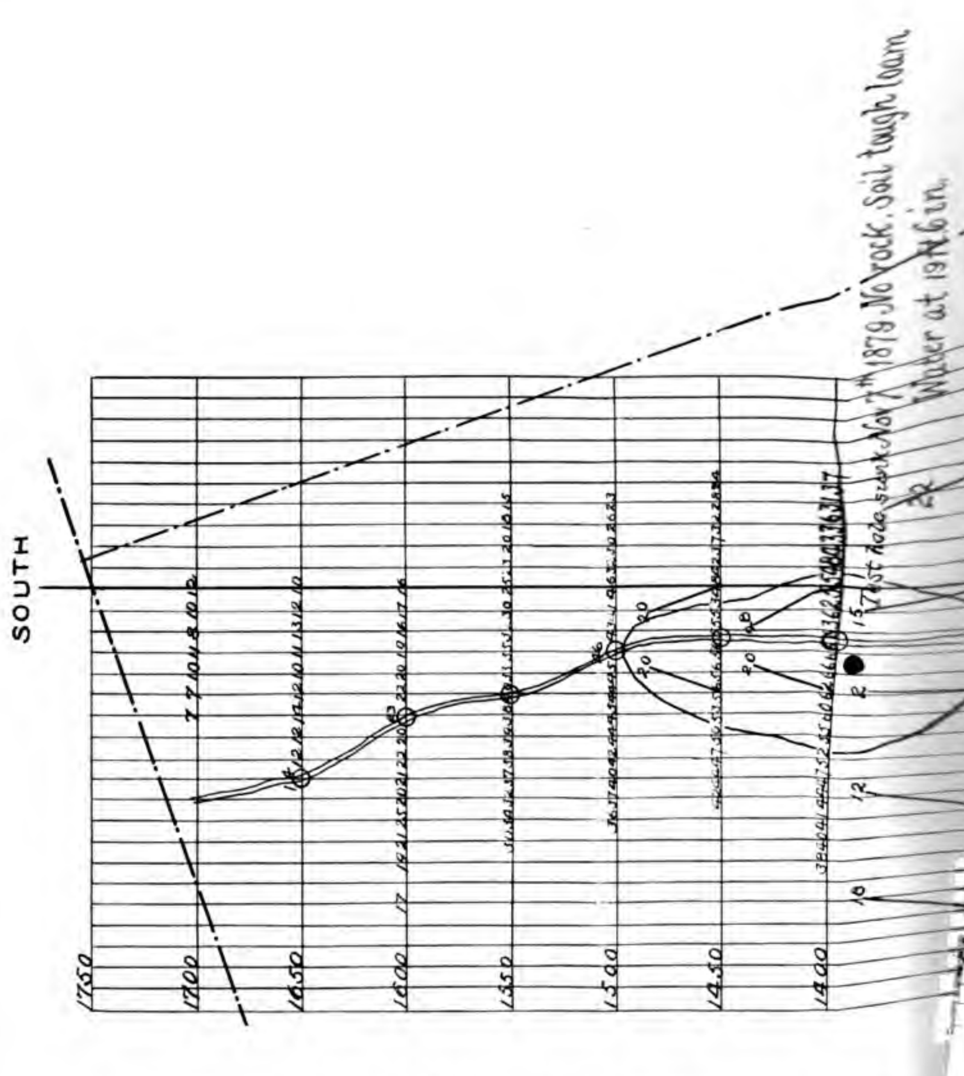
[1] In 1900 the concentrator made a run on 75,206 tons of rock, producing about 10,000 tons of 63% ore. This is a yield of about 13% of 63% ore, or 12% of 72% ore (see page 278).

hornblende, forming bands of nearly black rock interlayered with the lighter-colored gneisses, but when the ore is rich the proportion of black silicates is small and the veins are very inconspicuous. Where covered with glacial drift or with the products of rock weathering it is impossible to detect them. In some places, where the drift covering is thin, the ore and associated minerals weather to a coarse gravelly mass with a rusty-red color, and by this means the veins may be traced. But there are other rocks that also disintegrate and weather red, so that this feature is not always to be relied upon as indicating ore veins.

Fortunately, however, this ore is magnetic, so that by tracing lines of magnetic attraction on the surface the positions of ore-bearing rocks beneath the surface may be outlined. It is to be remembered, however, that much of the pegmatite of the Highlands is magnetite-bearing and that the Pochuck gneiss always carries large quantities of the mineral, which may attract the magnetic needle even when it is not in definite ore bodies. Hence, the discovery of a line or band of attraction is not always proof of the existence of a deposit of workable ore. When the band is continuous and its breadth is comparatively great—that is, when the magnetic area is a broad one—the chances for the discovery of good ore are greater than when it constitutes a line, even though the strength of the attraction may be comparatively slight.

In several instances magnetic surveys have shown their value in locating ore-bodies in the Highlands. One of the best illustrations of this use of the compass and dip needle is exhibited by the survey of the Washington mine property near Oxford Furnace, made by W. H. Scranton in 1879. His map is reproduced in Plate I. The small figures on the east-west lines indicate the magnetic dips, and the figures at the ends of the long lines inclined toward the locus of the vein indicate the magnitudes of the variation. The double line is the approximate position of the center of the vein a short distance below its exposure at the rock surface beneath the soil. The conclusions deduced by Scranton from the study of a large number of observations made within the State are as follows:[1]

[1] Annual Report of the State Geologist for 1879, p. 98.



FROM ANNUAL REPORT OF STATE GEOLOGIST FOR 1879, PAG

"An attraction which is confined to a very small spot and is lost in passing a few feet from it is most likely to be caused by a boulder of ore, or particles of magnetite in the rock.

"An attraction which continues on steadily in the direction of the strike of the rock for a distance of many feet or rods indicates a vein of ore; and if it is positive and strongest towards the southwest, it is reasonable to conclude that the vein begins with the attraction there; if the attraction diminishes in going northeast, and finally dies out without becoming negative, it indicates that the vein has continued on without break or ending until too far off to move the compass needle. If, on passing towards the northeast, along the line of attraction, the south pole is drawn down, it indicates the end of the vein or an offset. If, on continuing farther still in the same direction, positive attraction is found, it shows that the vein is not ended; but if no attraction is shown, there is no indication as to the further continuance of the ore.

"In crossing veins of ore from southeast to northwest, when the dip of the rock and ore is as usual to the southeast, positive attraction is first observed to come on gradually, as the ore is nearer and nearer to the surface, and the northwest edge of the vein is indicated by the needle suddenly showing negative attraction just at the point of passing off it. This change of attraction will be less marked as the depth of the vein is greater, or as the strike is nearer north and south. The steadiness and continuance of the attraction is a much better indication of ore than the strength or amount of attraction is. The ore may vary in its susceptibility to the magnetic influence from impurities in its substance; it does vary according to the position in which it lies—that is, according to its dip and strike; and it also varies very much according to its distance beneath the surface."

Other illustrations of the use of magnetic attractions in surveying land containing magnetic ore may be found in the State Survey Report for 1873.[1] For a description of the construction of the instruments employed in making magnetic surveys and a discussion of the theory underlying their use the reader is referred to a recent article by Prof. H. L. Smyth[2] in which several examples of the manner of interpreting such surveys are outlined.

After locating the approximate position of the ore by magnetic surveys or by some other method recourse should be had to the diamond drill to determine its more accurate position and its extent and quality. Test pits and trial shafts may be employed for this purpose, but it must be remembered that these can reach only shallow depths, whereas the depth to which the drill can

[1] Annual Report of the State Geologist for 1873, p. 91–95.

[2] Economic Geology, Vol. II, No. 4, 1907, p. 367–379; Vol. III, No. 3, 1908, p. 200–218.

explore is practically as great as the lower limit of economical mining.

Of course, the location of the permanent plant of a mine should not be determined upon until the course of the ore underground has been established. While most of the ore veins in the Highlands strike northeast and dip southeast a few are known to strike and dip in other directions. The usual pitch of the ore bodies is northeast, but here again there are departures from the rule. Moreover, the amounts of dip and pitch vary. In some places the dip of the vein is nearly vertical, while in others it is only 30° from the horizontal. The pitch may be as low as 12° to 15° or it may be as high as 45° to 50°. The permanent shaft should be located with reference to these features since through it the ore must be raised to the surface. A shaft that is favorably situated for the working of a steeply dipping and pitching deposit may be very unfavorably located with respect to one that dips and pitches at low angles. Consequently, the permanent shaft should not be started until all the elements of strike, dip and pitch have been determined. Fortunately, these can often be inferred from the corresponding features exhibited in rock exposures, which, over most of the Highlands, are abundant. When natural outcroppings are not available trenches and test pits will usually afford access to solid rock. The dip and pitch of the ore bodies in every instance that has come under observation correspond with these features in the associated gneisses. Hence, it is only necessary to measure the dip and pitch of these rocks near the vein to know the dip and pitch of the ore bodies. Care should be taken to make the measurements on fresh rocks, otherwise the results reached will often be misleading. This is especially true when the location of the vein is on a hillside, since on slopes weathered rocks, as a result of downward creep, often assume positions which are very different from those they originally occupied. Measurements of dip and pitch made on such exposures would, therefore, naturally lead to conclusions which might involve unnecessarily expensive investments in the mining plant.

CHAPTER X.

DESCRIPTION OF MAGNETITE MINES IN LIMESTONE.

CONTENTS.

The deposits of magnetite in the Franklin limestone are described separately from those in the gneisses principally because

of the slightly different character of their ore, which has been sufficiently emphasized in an earlier paragraph.

No very large magnetite mine has ever been developed in the limestone, the most important one being the Ahles mine, which at the present time is the only one being operated. Most of the limestone ventures are little more than explorations, and none of them has ever been worked continuously for long periods.

There is no record of the quantity of ore that has been obtained from these mines. A few have yielded abundantly for a few years, but no one in its entire history has reached an aggregate of 500,000 tons. The deposit at the Ahles mine promises to be the most productive of this class ever worked in the State.

Following the order employed in discussing the limonite mines, the magnetite mines that are situated in limestone areas will be described in groups beginning with the mine in the most westerly limestone area and continuing with those in areas successively further northeast, as follows:

The Schuler mine, the mines of the Belvidere group, the mines on Jenny Jump mountain, the Andover group of mines, the Roseville mine, the mines near Franklin Furnace and the Splitrock Pond mines.

(1) The Schuler Mine.

The Schuler mine is in an area of Franklin limestone which is one of a series of small areas that occur on the west slope of Scotts Mountain for a distance of 1½ miles north of Roxburgh. They are apparently the outcroppings of little patches only a few score feet wide that lie embedded in gneisses. In most cases the limestone is a white granular variety that is devoid of silicate minerals. The individual patches lie approximately along a straight line parallel to the structure of the gneisses, but so far as can be learned they are isolated from one another.

The Schuler openings were about three-quarters of a mile north of Roxburgh, near the corner of the roads to Montana and Belvidere, in Oxford Township, Warren County. An old opening made about 1770 was reopened in 1872 to a depth of 27 feet, and a new shaft was sunk 50 feet to the west. Both

were in a gray crystalline limestone, dipping steeply southeast. The deposit in the western shaft was 2 feet wide, and the ore was so soft that it was removed with pick and shovel. About 100 tons were taken out and the mine was abandoned. In 1880 it was again reopened, but after considerable drifting and the sinking of four additional shafts further east without finding workable ore, the project was again abandoned. During these explorations about 100 tons of ore were raised.

The ore was brownish-black, fine-grained and highly magnetic, and, like other ores occurring in the limestone, it contained considerable manganese.

On the topographic map of the State the mine is located three-quarters of a mile further north, at the next northerly road corner, but this is clearly an error, since no limestone occurs there, and no old mine pits are discoverable. The Warren County atlas, published in 1874, shows an iron mine on Schuler's farm at the point indicated above. Here there is an old pit in limestone, and this is taken to be the Schuler pit.

References: N. J. 1873, p. 73; 1879, p. 82; 1880, p. 116; 10th Census, p. 149.

THE BELVIDERE GROUP.

The Belvidere group of mines is situated in an area of Franklin limestone that occupies about 3.5 square miles in Oxford Township, Warren County. The area begins about half a mile east of Oxford Church, and extends east and north about 4 miles to Pequest Furnace.

The rock for the most part is a fine-grained, white or gray crystalline marble, remarkably free from impurities. At Pequest Furnace, chondrodite, serpentine and a few other silicates are present in large quantities, thus giving the rock a dark color, and at a point midway between Pequest Furnace and Oxford Church the limestone is impregnated with sphalerite to such an extent that an attempt has been made to utilize it as a source of zinc. At the Raub mine, about one-fourth mile northeast of the zinc exploration, the limestone also contains a few silicates and is dark-colored. At all these places dark, igneous rocks intrude the limestone, and it is to the influence of these probably that the

silicate impurities are due. Elsewhere the rock is so free from impurities that it was formerly quarried at many places as a flux, and is now being quarried about three-fourths of a mile west of the Ahles mine for use in the manufacture of Portland cement.

The principal openings in this area are: the Little, Riddle, Queen, Osmun, Ahles and Raub mines. Besides these there is an exploration about one-half a mile west of the Raub mine on the north side of the road, running north of east from Oxford Church.

(2) The Little Mine.

The Little or Fellows mine is about 1.5 miles northwest of Oxford Furnace and about the same distance east of Oxford Church, in Oxford Township, Warren County. Like most of the other mines in the vicinity, the Little mine was opened in 1870. It was operated for 3 years and was closed in 1873. The cause of its abandonment at this time is not known, though it may have been due to the fact that the mine was very wet. Later, in 1889, the mine was again opened, and in June, 1891, was leased by the Thomas Iron Company, and was operated until October, 1893, when it was again closed because of the low price of ore. During this period about 2,300 tons of ore were mined.

Two lines of attraction are reported to cross the property about 160 feet apart. Two shafts were sunk to a depth of 70 feet on the northwest one, and were connected by a drift. Later (in 1891) two other shafts were sunk, one in each deposit. Drifts from the western shaft seemed to show that the ore body at a depth of 50 feet is 14 feet wide, between limestone on the north and a "compact sandstone" on the south.

The ore on the surface was the mixture of ocherous limonite and crystalline magnetite, characteristic of all the mines in this area. The magnetite was distinguished as hard ore and the limonite as soft ore. Usually the two kinds were separated by washing, and only the hard ore was saved. Below the zone of weathering the ore was compact. Here it was probably a mixture of magnetite and calcite.

On the dump heaps are great quantities of limestone containing crystals and irregular masses of magnetite. When the large lumps disintegrate the limestone between the magnetite clumps dissolves and leaves a mass of limonite, which contains considerable manganese. In many of these lumps the relations of the ore to the rock can be seen to advantage. Some of the fragments are of great size, and are covered with a layer of limonite. Others are weathered in ridges, the ferruginous portions projecting above the general surface of the rock. On fresh fractures veins of magnetite can be seen running parallel to the structure of the limestone, as though formed by a replacement of the rock along bedding planes. In all cases the limestone has assumed a blue tinge, and is decidedly darker than the unaltered rock in ledges at a distance from the mine holes, which is nearly white. The limonite can not be detected in the unweathered specimens, but is developed only after they have been attacked by the atmosphere.

Several analyses of the ore made at different times indicate clearly its quality. An analysis of the compact variety obtained from beneath the zone of weathering gave:

Fe_3O_4	MnO	MgO	S	P_2O_5	*Ins.*	*Authority.*
94.76	1.00	.29	.10	.10	1.60	N. J. 1873, p. 75

A shipment of 375 cars, including 10 cars of unwashed ore, made in 1891, gave 55.34 per cent. Fe. The highest percentage of metal was shown by a shipment of 25 cars in July, 1891, which yielded 62.25 per cent. Fe, and the lowest in a shipment of 2 cars of washed ore, which gave only 37.94 per cent. Fe. The average of 531 cars shipped to the Thomas Iron Co. in 1893 was:

$Fe = 56.29\%$; $SiO_2 = 7.94\%$; $P = .103\%$; Authority, N. J. 1899, p. 167.

A sample (?) of black ore (probably washed ore) analyzed by Cooper & Hewitt gave:

FeO	Mn	Al_2O_3	CaO	MgO	P	S	Ti	SiO_2	*Authority.*
67.54	.90	.74	.31	.51	.02	.08	tr	1.20	N. J. 1899, p. 169

References: N. J. 1873, pp. 74–75; 1879, p. 83; 1890, p. 54; 1891, p. 236; 1896, p. 322; 1899, pp. 159, 167, 169; 1900, p. 205.

(3) The Riddle or Redell Mine.

The Redell or Riddle mine was a short distance east of the Little mine. It was evidently in operation before 1872, but is not mentioned in the Geology of New Jersey issued in 1868. It was closed in 1873, but was again opened in 1880 and worked for a short time and again closed. Operations were resumed once more in 1889, but only for a brief period. The mine was again opened in 1890, but shortly thereafter it was abandoned.

Three shafts were sunk in the deposit, the deepest of which was about 120 feet. The deposit was followed 200 feet east and west by drifting and was cross-cut for 50 feet, disclosing clay walls on both sides. The ore was "loose and crumbly," like that of most of the other mines in the vicinity, and required careful washing to make it marketable. The washed product, however, was reported to be of good quality. It contained about 1.5 per cent. of manganese and was of Bessemer grade.

Two analyses of ore taken from the "Bedell" mine are published in the Annual Report for 1899. It is probable that the ore was from the Redell mine. The results of the analyses, which were furnished by Mr. B. F. Fackenthal, are as follows:

	Fe	*Mn*	*Al_2O_3*	*CaO*	*MgO*	*P*	*S*	*TiO_2*	*SiO_2*	*Authority.*
1.	34.72	.35	6.41	9.14	3.10	.008	.584	.31	29.69	N. J. 1899, p. 166.
2.	34.93	.34	5.84	10.09	2.89	.012	.380	.21	29.54	N. J. 1899, p. 166.

References: N. J. 1872, p. 18; 1873, p. 74; 1879, p. 83; 1880, p. 116; 1890, p. 54; 1891, p. 237; 1899, p. 166.

(4) The Queen Mine.

The Queen or Belvidere mine was a few hundred yards south of the Redell mine in Oxford Township, Warren County.

It was opened in 1882 after a careful survey with the dip needle over a line of attraction running east-west. The property was tested by two vertical shafts and several pits. Drifts in one of the shafts, which was 75 feet deep, disclosed an ore body 25 feet wide between walls of ferruginous clay or much decomposed rock, dipping south. About 200 feet south of this shaft a large pit was dug, and in this a lean ore was uncovered that

contained streaks rich in magnetite. This was about 60 feet wide, and apparently trended east-northeast. About 200 feet east of the pit a second shaft was sunk to 60 feet. In this year about 2,000 tons of ore were raised. During the succeeding year the shafts were lowered to 100 feet and 15,000 tons of ore were mined. Since the ore body in the northern shaft was traced by an east-west drift about 140 feet, it is probable that there are two parallel veins present about 200 feet apart.

It is not known how long the operations were continued at this time. However, the mine was closed and reopened in July, 1889. During the following two years extensive prospecting was done. Two new shafts and an incline were put down, the deepest being 155 feet, and the ore body was opened up for a distance of 200 feet along the vein, which was found to be 40 feet wide. The mine was operated until 1893, yielding a large product (about 1,800 tons monthly). In this year it was closed because of the low price of ore and remained closed until 1899, when preparations were made for resuming operations. During the early portion of the following year a little ore was raised through one shaft, but later all work was suspended.

The ore was very much like that of the Little mine. It was a mixture of limonite and magnetite that was washed before shipment. Early analyses reported the presence of about 4 per cent. manganese, a very small quantity of phosphorus and almost no sulphur. Later analyses, however, did not corroborate these figures. The ore shipped in 1890 contained about 57 per cent. Fe, and some of it was so low in phosphorus that it came under the Bessemer limit. Large shipments, made a little later, were found to contain considerable phosphorus.

Fe	*Mn*	*P*	*Insol.*	*Authority.*
1.—55.29				N. J. 1899, p. 167.
2.—55.12		.229	9.81	N. J. 1899, p. 167.
3.—54.35	1.264	1.52		N. J. 1899, p. 167.

1.—Shipment of 343 cars to Thomas Iron Co. in 1892.
2.—Shipment of 16 cars to Thomas Iron Co. in February, 1893.
3.—Sample from stockhouse, Hellertown, Thomas Iron Co., 1893.

References: N. J. 1882, pp. 71–73; 1883, p. 141; 1890, p. 54; 1891, pp. 235–236; 1896, p. 322; 1899, pp. 159 and 167; 1900, p. 205.

(5) *The Osmun Mine.*

The Osmun mine was about a mile northeast of the Queen mine and about an equal distance northwest of Oxford Furnace, in Oxford Township, Warren County.

A number of trial pits sunk in 1882 found ore like that of the Queen mine in the Franklin limestone. About 400 tons were raised during the year. In 1885 two more shafts were sunk and 200 tons of ore were mined. This contained about 1 per cent. of manganese. Very little mining was done, however, and operations soon ceased. At the beginning of the year 1891 explorations began anew and many new test pits were dug, ranging in depth from 10 feet to 40 feet. These yielded 600 tons of ore like that of the Queen mine.

Four carloads of the ore shipped to Cooper & Hewitt gave:

Fe	*Mn*	*P*	*Authority.*
1.—58.302	1.084	.033	N. J. 1899, p. 168.
2.—55.73		.065	N. J. 1899, p. 168.

In 1901 work was resumed. A new shaft was begun in glacial drift south of the old workings, but it was not completed until the succeeding year. The mine was later known as the Osmun-Robeson or Ahles mine (which see).

References: N. J. 1882, p. 73; 1885, p. 106; 1891, pp. 237–238; 1899, p. 168; 1901, p. 137.

(6) *The Ahles Mine.*

The Ahles or Osmun-Robeson mine is in the same general area as the old Osmun mine, but a little south of the old workings. It is on the east side of the road from Oxford Furnace to Bridgeville, about a mile north of the former place in Oxford Township, Warren County.

A shaft was begun in 1901 and continued during the succeeding year until it attained a depth of 168 feet. At depths of 75 and 128 feet drifts were run southwest to the ore body, which was 30 feet distant. At the upper level the deposit was 40 feet wide to a horse of pegmatite from 2.5 to 30 feet thick. Beyond this the ore body was 24 feet wide, and beyond this to the south

was a much decomposed siliceous rock that gradually passed into a banded gneiss that resembles the Byram gneiss on the hill to the south. The dip of the ore vein is 80° south. On the foot wall is a finely banded gray gneissoid rock which in the hand specimen closely resembles some phases of the Byram gneiss. In thin section under the microscope its true character is revealed as that of a much metamorphosed and silicified limestone. It is composed of colorless pyroxene, calcite, a little biotite and some serpentinized chondrodite. The more siliceous bands consist mainly of oligoclase, microcline, green augite, green hornblende and calcite. The ore is apparently on the contact between this rock, which may be a metamorphosed limestone, and the gneiss to the south. In this respect it differs from the ore of the mines to the west, which is well within the limestone, at some considerable distance from any igneous rock.

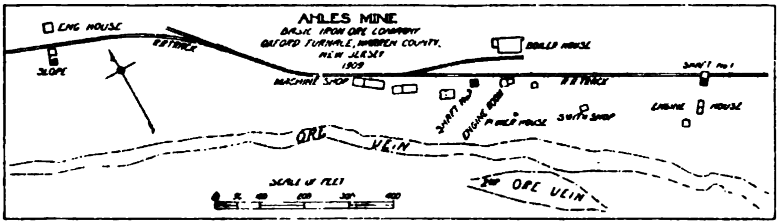


Fig. 13.

Map of surface of Ahles mine. (Courtesy of Basic Iron Ore Company.)

In the following year two other shafts were sunk and drifts were driven for a distance of 760 feet along the vein, developing ore throughout their entire lengths. The three shafts were completed and a slope to the 200-foot level was constructed further west in 1907. During 1908 a drift at the 200-foot level was driven a distance of 1,800 feet in ore to connect with the drift from shaft No. 1. No. 3 shaft was driven to the 250-foot level and a drift was started toward the ore body. The shaft and slope are northeast of the ore deposit, which has a width of from 20 to 40 feet (Fig. 13).

South of the ore body is the horse of pegmatite referred to above, and south of this is a second ore body, which is from 5 to 30 feet wide, but is very short. Only three of the shafts are

working at present, No. 2 having been abandoned. The depths of the three working shafts are as follows: Shaft No. 1, to the southeast, 200 feet; shaft No. 3, a few hundred feet west of No. 1, 250 feet; slope about 1,000 feet west of No. 3, 208 feet. The mine has been operated continuously up to the present time, and has produced about 215,000 tons of ore. That raised prior to 1904 was all obtained in the course of the development work.

The ore is a mixture of soft brown limonite, containing nodules of pyrolusite and crystals of magnetite, and often enclosing boulders of limestone, in which the limestone is partially replaced by limonite. There are also present in the ore great masses of chert or cherty limonite. Many of the large lumps of this material on the dump are gashed and jointed, and the surfaces of the cracks are coated with cherty quartz.

A partial analysis of the material raised in 1902 gave:

Fe	*Mn*	*S*	*P*	*Ti*	*SiO_2*	*H_2O*	*Authority.*
46.0	4.0	0	0	0	10.72	10.0 & 12.0	N. J. 1903, p. 101.

A second and more careful analysis of the ore dried at 212°, which was made in 1904, gave:

Fe	*Mn*	*Al_2O_3*	*CaO*	*MgO*	*S*	*P*	*SiO_2*	*Authority.*
47.65	4.35	1.35	1.26	1.64	.038	.092	15.705	N. J. 1904, p. 295.

A complete analysis of the ore as shipped in 1905 is given on page 111.

References: N. J. 1902, pp. 116–117; 1903, pp. 100–102; 1904, pp. 294–5; 1905, p. 317; 1906, p. 175.

(7) The Raub Mine.

The Raub mine was about three-fourths of a mile northeast of the Redell and Little mines on the south slope of the hill over which passes the road between Buttzville and Oxford Furnace. The principal mine holes are on the east side of this road and north of the road between Oxford Church and Pequest Furnace, in Oxford Township, Warren County, though a few of the older pits are on the west side of this road.

Several test pits were put down in 1872. One of these passes through 68 feet of a soft decomposed rock and several feet of

brown earthy manganiferous ore, which was thought to dip north. The second pit, which was southwest of the first one, showed the same kind of ore. It bottomed in magnetite, associated with limestone. Prospecting continued until 1875, by which time one of the pits had been developed into a shaft 90 feet deep. Drifts of 200 feet disclosed an ore vein striking a few degrees south of west. In the southwest pit, now also changed to a shaft, a little sphalerite was found. No work was done between 1875 and 1890, but in this year prospecting was resumed. A new shaft was sunk, and this in the succeeding year struck a deposit of ore 6 feet thick. Shortly thereafter the mine was closed. It probably never produced much ore.

The ore that was found was like that of the other mines in this limestone area. It was a fine, earthy, manganiferous mixture of soft (limonite) and hard ore, some of the former of which was used as a paint.

Partial analyses of the ore removed in the course of the prospecting operations were as follows:

Fe	*Mn*	*P*	*SiO₂*	*H₂O & organic*	*Authority.*
1.—49.34	5.81	.11		13.55	N. J. 1873, p. 75.
2.—33.80	1.836	.192	24.82		N. J. 1899, p. 168.
3.—63.87	.512	.118	2.97		N. J. 1899, p. 168.

1.—Soft, earthy ore removed from northeast pit in 1872.
2.—Soft, earthy ore, probably washed. Analyzed by Thomas Iron Co., 1896.
3.—Hard ore separated from soft ore. Analyzed by Thomas Iron Co., 1896.

References: N. J. 1873 p. 75; 1879, p. 83; 1890, p. 54; 1891, p. 237; 1899, p. 168.

THE MINES ON JENNY JUMP MOUNTAIN.

The Franklin limestone on Jenny Jump Mountain occurs in two narrow belts running northeast, or parallel to the crest of the ridge. The most conspicuous of these borders its east side for a distance of about 5 miles. At its northeast end the limestone is intimately associated with siliceous beds that are supposed to be metamorphosed calcareous sandstones, and is cut by large dikes of basic igneous rocks. The limestone and associated sandstones are folded into complex folds, which occupy on the surface an area of about 2 square miles. In this are situated the many openings of the Howell and Shaw mines.

South of this area the limestone extends southwest, with several interruptions, along the base of the mountain as a narrow, straight strip a few hundred feet wide. In this strip are the Welch and Inshow explorations.

The second belt is exposed only by explorations in search of ore. It runs along the hollow on the southeast side of the crest of the mountain, possibly as a series of small lenses embedded in the gneiss. It is found in the pits of the Smith, Hoagland, Deats, Stinson, Davis and Albertson mines, but only in such small quantity that the mines have heretofore been considered as being in the gneiss.

(8) Smith's Mine.

Smith's mine was about three-fourths of a mile northeast of Green's Pond in Hope Township, Warren County.

The mine was first explored in 1873 by two shafts 20 feet deep. Immediately under the soil the shafts encountered a brownish-black ore resembling that of the mines in the white limestone northwest of Oxford Furnace. This ore contained 45 per cent. of Fe and 6.5 per cent. MnO, and had associated with it some calcite, white mica and asbestos. Below this was hard black ore like that at the Deats mine a mile further northeast.

The place was not worked until 1882, when a small quantity of ore was raised.

References: N. J. 1873, p. 81; 1879, p. 83; 1882, p. 73.

(9) The Deats Mine.

The Deats Farm, or Dietz, mine, was on the east side of the valley of the stream that flows into Green's Pond, in Hope Township, Warren County. It was about 1.5 miles northeast of the head of Green's Pond and about the same distance southwest of the Kishpaugh mine.

The mine was first opened by a shaft 22 feet deep, which penetrated an ore composed of magnetite and hornblede. There was some calcite reported in the hanging wall and a few nodules of pyrite scattered through the rock. A trench 200 feet west of the

shaft uncovered a magnetitic gneiss. On the dump-heap of the mine there is considerable impure limestone containing dark mica and other silicates that are characteristic of the rock where it is in close contact with basic intrusives. In some fragments the limestone is cut by dikes of a gabbroitic rock.

The mine was never worked until 1882, when a little ore was taken from it. It has long since been abandoned.

References: N. J. 1873, pp. 81–82; 1879, p. 83; 1882, p. 73.

(10) *The Hoagland Mine.*

The Hoagland or Hendershot Farm mine was also in Hope Township, Warren County, but its exact location is a matter of some doubt, as it is very differently located in different reports of the Survey. It is possible the openings made at different times were in different places on the Hendershot farm, and that to this fact is due the confusion in the description of its location. The principal opening was apparently about 100 rods southeast of the Deats mine.

It is probable that openings were first made in 1873. These, however, could have been nothing but shallow explorations, as the place is described as a new discovery in the State Report of 1880.

In 1879 a shaft 50 feet deep was sunk in a vein of ore from 2 to 5 feet wide. Several hundred tons of ore, containing manganese and a very little phosphorus, were mined during this and the succeeding year, but since that time, so far as the record goes, nothing further has been done. The situation of the mine and the character of the ore suggests that the deposit is associated with limestone. West of the main shaft is a small pit with a dump on which is a little limestone. The conditions are apparently the same as at the Deats mine.

References: N. J. 1879, p. 83; 1880, pp. 117 and 127; 10th Census, p. 149.

(11) *The Stinson Mine.*

The Stinson mine was on the east slope of Jenny Jump Mountain about 1.5 miles from its northeast end, in Independence Township, Warren County.

The place was explored in 1879 by a shaft and some drifts. The rocks near the mine were reported as being gneisses and limestones. The place was not worked because of its great distance from the railroad. With the completion of the Lehigh & Hudson River Railroad in 1881 explorations were resumed, and a second shaft was sunk 123 feet in a vertical vein from 1 to 3 feet wide. In 1882 the width of the vein had increased to 7 feet, but shortly thereafter the mine was abandoned.

The ore, three samples of which were analyzed with the results indicated below, has the general character of the ores in limestone. Most of it contained calcite and garnet.

No. 1	*Fe*=63.12;	*P*=.017;	*S*=— ;	*Mn*= .65	N. J. 1879, p. 85.
No. 2	=60.66	=.006	=tr ;	= .40	N. J. 1879, p. 85.
No. 3	=49.79	=.02	=0 ;	=2.74	N. J. 1879, p. 85.

References: N. J. 1879, pp. 84–85; 1881, p. 37; 1882, p. 74.

(12) The Davis Mine.

Davis's mine was on the top of Jenny Jump Mountain, at its northeast end, in Independence Township, Warren County.

It was opened in 1873 by a shaft 25 feet deep, at the bottom of which was a layer of ore a foot wide in rocks dipping southeast. The ore contained pyrite and calcite, some chalcopyrite and azurite. The latter was observed principally as thin coatings in seams of the rock. On the hanging-wall side the calcite was in such large quantity as to constitute an impure limestone.

The place was never worked extensively. A small quantity of ore was raised in 1880 and in 1881. Work was resumed in 1883 a little farther east, down the slope of the ridge, on the top of which were the old openings, and 7 feet of ore were developed. The deposit dipped toward the southeast. This was lean and contained considerable calcite. After working it for six months the place was abandoned.

N. J. 1873, p. 35; 1879, p. 85; 1880, p. 117; 1881, p. 38; 1883, p. 143.

(13) The Albertson Mine.

The Albertson mine was about 400 yards west of the oldest shaft of the Davis mine, on Jenny Jump Mountain, in Independence Township, Warren County.

The mine was opened in 1873 by a test pit that passed through 14 feet of clay and struck an ore belt 7 feet wide. This lay on rock which dipped southeast at about 20°. It was probably a surface deposit that had been transported from elsewhere. From its character it is presumed to have originated in limestone.

An approximate analysis gave:

Fe_2O_3	*MnO_2*	*Insol.*	*H_2O*	*Fe*	*Mn*	*Authority.*
78.61	5.20	10.40	5.00	55.6	3.3	N. J. 1874, p. 58.

References: N. J. 1873, p. 85; 1874, p. 58; 1879, p. 85.

(14) The Inshow Exploration.

The Inshow explorations were on a low limestone and gneiss ridge at the east base of Jenny Jump Mountain, about a mile north of the Hope-Danville road and a few rods east of the road skirting the east side of the mountain, in Hope Township, Warren County.

Two pits were dug in 1872 disclosing a lean ore in white crystalline limestone with a steep dip to the northwest. The ore was lean, but manganiferous. It seems to have been present in very small quantity only. In a pit on the adjoining Welch farm to the north only thin strings of ore were found. These are connected with the southern pit by a weak line of attraction.

A specimen of the ore containing garnet, hornblende, and calcite gave:

Fe	*Mn*	*S*	*P*	*Authority.*
51.40	.79	.00	.017	N. J. 1879, p. 84.

The limestone in the vicinity contains graphite, hornblende, mica, garnet and serpentine.

References: N. J. 1873, p. 84; 1879, p. 84.

(15) The Shaw Mine.

The Shaw mine in Independence Township, Warren County, on the east side of Jenny Jump Mountain, is one of the oldest mines on this ridge. The mine consisted of several openings on both sides of the road from Danville to Southtown, some being

in white limestone and others in gneiss. They were opened many years before the appearance of the Report of 1868, but were not in operation at that time. In 1871, however, they were apparently reopened and worked for a short period and then abandoned.

The pit in limestone was on the east side of the road and 150 yards distant, at the southwest end of a limestone ridge. The vein of ore is said to be 18 inches wide and to dip northwest. An opening northeast of this one was distant several hundred yards and was in gneiss. The pit was 12 feet long, 5 feet wide and 7 feet deep. Northeast of this a few hundred yards was a third opening of the same size as the last one, and this, too, was in gneiss. The ore from both of these openings was reported to be good. Analyses were:

	Fe_3O_4	SiO_2 *and ins.*	*S*	P_2O_5	*Met. iron*	*Authority.*
1.	—81.6	16.2	0	0	59.1	N. J. 1868, p. 660.
2.	—75.7	15.0	.9	0	54.8	N. J. 1868, p. 660.

1.—Ore from southwest opening in gneiss.
2.—Ore from northwest opening in gneiss, on west side of road.

Later reports declare that the ore from the pit in limestone carried considerable manganese and some magnesium and calcium carbonate. The percentage of metallic iron in the ore raised in 1872 was 58.5 per cent.

References: N. J. 1868, pp. 659–660; 1872, p. 18; 1873, p. 85; 1879, p. 85.

(16) *The Howell Farm Mine.*

The Howell Farm mine comprises a number of independent openings in the Franklin limestone at the northeast end of Jenny Jump Mountain in Independence Township, Warren County.

Several of the many pits and tunnels on the property were opened in the early part of the last century. In 1872 some of these were re-explored and several new shafts were sunk. The northernmost shaft was at the north end of a line of strong attraction that crossed the limestone ridges in a north-south direction. In this the ore was found to be 10 feet thick, including some layers of limestone. Its dip was 70° southeast. An adit tunnel driven in from the west to strike the vein below the shaft

is 150 feet long through a hard gray gneiss, which is cut at one place by a narrow trap dike. About 300 yards southwest of these openings others were made in a vein 8 feet wide, which dipped 60° southeast. A large quantity of calcite and graphite accompanied the ore, an analysis of which is given below. No ore was shipped during this year, and no systematic mining was attempted. It is not known whether any extensive explorations were made later or not, but it is quite certain that the mine never shipped any large amount of ore.

Several analyses of the ore from the property have been published. The samples analyzed were probably all from the southwest opening described above.

Fe_3O_4	Al_2O_3	MnO	CaO	MgO	S	P_2O_5	TiO_2	SiO_2	CO_2	C
1.—83.63a	2.67	.65	4.82	1.22	1.09b	.10	0	.60	4.63	.70
2.—78.96	d	2.70	d	d	tr	.06	0	11.70c	d	d
3.—73.27	d	1.80	3.71	d	1.24	.85	0	10.20c	d	d
4.—70.06	d	2.60	6.49	1.30	.18	.43	0	10.10c	d	

a=Iron recorded as Fe_2O_3.
b=Sulphur recorded as SO_3.
c=Includes all material insoluble in acid.
d=Known to be present, but not determined.

1.—Fe = 58.50;	S = .43;	P = .05.
2.— " 57.17;	" tr;	" .26.
3.— " 53.05;	" 1.24;	" .37.
4.— " 50.72;	" .18;	" .19.

1. Average ore from southwest opening of 1873. N. J. 1873, p. 86.
2. Brownish-black, earthy ore containing graphite. From west side of deposit at Shaft No. 4. N. J. 1878, p. 101.
3. Hard, blue-black ore containing graphite and feldspar. Middle of deposit at Shaft No. 4. N. J. 1878, p. 101.
4. Fine grained, hard, brown-black ore. From east side of deposit at Shaft No. 4. N. J. 1878, p. 101.

References: N. J. 1872, p. 18; 1873, pp. 85–87; 1878, p. 101; 1879, p. 85.

THE ANDOVER GROUP.

The mines included in the Andover group are the Glendon, the Sulphur Hill and a portion of the Tar Hill openings. The Sulphur Hill mine is the only one that has ever been important. This mine and the Tar Hill mine are usually regarded as being on the same vein, but it is doubtful if this is so. The Glendon mine appears to be in a distinct deposit that is apparently very short.

The Franklin limestone in this vicinity, as at Roxburgh, occurs in a series of small exposures in a straight belt, which extends northeast from near Decker Pond to a point about 1 mile above Andover, where the rock was formerly quarried. The Glendon mine is at the east margin of this belt near its contact with Cambrian sandstone.

A second belt lies about half a mile west. This is exposed only at the Sulphur Hill and the Tar Hill mines. It is very narrow, and like other similar occurrences, may be simply a line of inclusions embedded in the gneiss.

(17) The Glendon Mine.

The Glendon or Chapin mine was in Green Township, Sussex County, on the northwest slope of Allamuchy Mountain, on the east side of the road from Andover to Allamuchy and about 2.25 miles southwest of Andover.

The mine was probably opened about 1850 and worked for several years. By 1868 four shafts had been sunk, one of which was 70 feet deep. The mine probably never produced much ore.

The ore contains much pyrite, hornblende and garnet and a great quantity of calcite. It is reported also to be manganiferous. In the neighborhood of the openings there is a great deal of pegmatite, and in the openings themselves a large quantity of scapolitic diorite. The ore occurs as magnetite crystals embedded in calcite, which contains in addition numerous garnets. The peculiar character of the ore seems to be due to the action of the basic igneous rock, which is evidently intrusive. So far as can be seen now, the ore deposit does not occur in a distinct lens, but rather as an irregular impregnation in the limestone.

References: N. J. 1855, p. 163; 1868, p. 628; 1873, p. 88; 1879, p. 86.

(18) The Sulphur Hill Mine.

The Sulphur Hill mine was the name given to the northernmost openings of the Andover mine (see page 79), situated about 2 miles north of Andover, in Andover Township, Sussex County.

The mine occupied the higher portions of the slopes of a ridge overlooking Hewitt's Pond. Although usually considered a part of the Andover mine, it was opened in a distinct deposit, which was a short distance west of the line of strike of the Andover deposit. Moreover, calcite was absent from the ore of the Andover mine while present in that of the Sulphur Hill mine. Further, the ore of the former was a mixture of hematite and magnetite, while that of the latter is magnetite, with which is associated a large number of different sulphides.

The mine was opened some time between 1855 and 1860, and was operated for a few years when it was abandoned (about 1863). It was later reopened and worked in 1871 and 1872, and in the latter year was again closed, because of the great quantity of sulphur in the ore. It was again reopened in 1879 and worked through this and the succeeding year. It was then abandoned permanently. During the census year 1879-1880 ore to the amount of 15,201 tons was raised.

At this time the main excavation was 65 feet to 75 feet deep, about 30 feet wide and 100 feet long. The pit was entered by a tunnel 175 feet long. A second opening, known as the northwest pit, was 20 feet deep. It was situated on the northwestern or "back" vein.

The Sulphur Hill deposit is remarkable for the great number of minerals occurring with the magnetite, among them being compounds of zinc, copper and lead. The most important are willemite, garnet, calcite, quartz, sphalerite, galena, chalcopyrite, pyrite, malachite, azurite, hematite, limonite, talc, biotite or phlogopite, epidote, fluorite and a sesqui-oxide of manganese.

The ore-bearing belt in which the deposit lies is from 50 to 60 feet wide, extending from a point opposite the north end of Hewitt's Pond to the openings of the Tar Hill mines, a mile to the northeast. The ore deposits, which are two in number, are in gneiss, but they are bordered on the southeast side by a narrow zone of a quartz-garnet rock composed of garnet, epidote, quartz, feldspar and hornblende. The ore deposits consist of a mixture of crystalline magnetite intermingled with calcite, garnet and many of the other minerals enumerated above. The galena, sphalerite and chalcopyrite were associated together in bunches in

the calcite, particularly in the rock between the two ore veins, and occasionally crystals of magnetite were found embedded in the galena. Much of the galena was argentiferous. A specimen of mixed galena and rock yielded 19.5 oz. silver per ton, and a specimen of mixed galena and pyrite 17.02 oz. per ton. The quartz occurred as large "gatherings" in calcite and smaller ones in galena. On the other hand, galena was observed occasionally in quartz, and in some cases on the contact between quartz and feldspar.

The garnet occurred in a great variety of colors, from dark red to light yellow. It constituted in some places the principal component of the aggregate. In other places it was present in small quantity only. It was present sometimes in "gatherings" within a mass of feldspar and hornblende, and sometimes it was found as a matrix surrounding these minerals.

It was noted in early descriptions of the mine that there seemed to be a definite relation between the galena and the magnetite of such a character that when the former was abundant the latter was also in large quantity, and vice versa. On the other hand, with a diminution in the proportion of the lead sulphide present, there was also a diminution in the amount of magnetite, its place being taken largely by garnet.

In the southeast portion of the opening calcite is the predominant material.

> "Here calcareous spar, sometimes of a highly crystalline structure, and sometimes of a compact, forms the base throughout which green sahlite (a variety of pyroxene), iron pyrites, magnetic iron ore, garnet, feldspar, etc., are disseminated. Highly interesting is the occurrence of nearly regular seams of calcareous spar, from the thickness of a leaf of paper to half an inch in thickness in a rock chiefly composed of magnetic iron ore and garnet. Not infrequently a narrow seam of calcareous spar, of a yellowish-white color, and of a subcrystalline texture, is seen penetrating a larger, irregular-shaped gathering of highly crystalline calcareous spar, of a bluish-gray color. * * * Occasionally the calcareous spar forming the narrow seams contains small particles of iron pyrites."[1]

Much of the rock associated with the ore is such as might be found by the metamorphism of limestone. Spencer reports that masses of the altered limestone are enclosed in gray gneiss, and that pegmatite is present near the ore.

[1] Geol. of New Jersey, 1868, p. 647.

The later working showed that the ore existed in two parallel deposits striking northeast and dipping southeast. The southeast deposit was found to be a shoot pitching 30° northeast. The galena, pyrite and chalcopyrite were found almost exclusively between the deposits in a rock, which was principally a mixture of garnet, calcite and hornblende.

The character of the ore and its associates suggests that it was formed by the replacement of limestone, the remnants of which are represented by the quartz-garnet rock.

Samples of the ore were analyzed by the chemists of the tenth census with these results:

Fe	*Mn*	*S*	*P*	*Ti*	*Authority.*
1.—42.63	....	2.290	.024	....	10th Census, p. 151.
2.—36.91	....	2.527	.022	....	10th Census, p. 151.
3.—46.53		.786	.020		10th Census, p. 153.
4.—32.73	....	.270	.100	....	10th Census, p. 151.

1.—Chippings taken around north and west sides of mine. Contained garnet, pyrite and pyrrhotite.
2.—Sample from 80 tons cobbed ore on dock.
3.—Sample of shipping ore after roasting.
4.—Sample of stringers of brown ore in magnetite, probably produced by surface alteration of the magnetite.

A complete analysis of Sample No. 2 is quoted on page 111.

References: N. J. 1855, p. 152; 1868, pp. 642–647; 1873, p. 88; 1879, pp. 86–87; 1880, pp. 118–177; 10th Census, pp. 151–153; 1883, p. 145; Folio U. S. G. S. No. 161, p. 21; Folio 2, Geol. Atlas of New Jersey, p. 21.

(19) The Tar Hill Mines.

The Tar Hill mines are about a mile northeast of the Sulphur Hill mine, near the top of the same ridge, in Andover Township, Sussex County.

The ore-bearing belt extends with many interruptions from the Sulphur Hill openings to those of the Tar Hill mine without any essential change in character. On this are the deposits which have been opened up in the many pits of the Tar Hill group.

The first openings were made some time prior to 1855, as in that year large abandoned pits are known to have existed. One of these was 70 feet wide and 60 feet long, and the other 100 feet long and 10 feet wide. The ore on the dumps of these was a

mixture of magnetite and pyrite, with the latter often predominating. Among the other minerals noted in the dumps were epidote, calcite, pyrrhotite, hornblende and garnet. An impure limestone was found on the dumps of some of the smaller pits. Between 1867 and 1873 the mine was in operation, but since the latter date, so far as is known, it has been idle. In 1880, however, a tunnel was cut into the hill from the south side. It penetrated a lean garnetiferous ore, which apparently was the lower portion of a deposit which at the surface was rich enough to warrant working. Although the ore was enclosed between distinct walls, it was not thought worth while to try to mine it. The place was therefore abandoned permanently. While active it was probably operated very vigorously, as the ruins of six shafts are still to be observed on the crest of the hill beyond the highest point.

The composition of the ore raised in 1867 was as follows:

Fe_3O_4	S	P_2O_5	SiO_2 and Ins.	Met. iron	Authority
73.6	1.1	tr	20.6	53.3	N. J. 1868, p. 658.

Half a mile further northeast on the crest of the ridge are two other pits, known as the Longcove mine. They were abandoned before 1855. Both were small openings in a seam of pyritiferous ore a few feet wide. The materials found on their dumps are the same as those found at the Tar Hill pits.

From the nature of the ore on Tar Hill and its associated rocks it seems probable that it is similar in its origin to the ore of Sulphur Hill, although the quantity of limestone present is much less. The limestone layer was probably much thinner, and consequently nearly all of the rock was changed to silicates. The magnetic attraction in the neighborhood of the pits is very strong.

References: 1855, p. 147; 1868, pp. 657–658; 1873, p. 88; 1879, p. 87; 1880. p. 118; 1883, pp. 145–146; Folio U. S. G. S. No. 161, p. 21; Folio No. 2, Geol. Atlas of New Jersey. p. 21.

OTHER MINES.

In addition to mines of the groups described above there are several others which seem to be on isolated deposits in that they are widely separated, and so far as known have no connection

with each other. These are the Roseville, Sterling Hill, Pike's Peak and Split Rock Pond mines.

(20) The Roseville Mine.

The Roseville mine is about 3.5 miles southeast of Andover in Byram Township, Sussex County, and about one-half mile east of Wright's Pond. It is in a more or less isolated situation, on a deposit that is apparently independent of any well-defined vein. The deposit is partly in gneiss and partly in limestone, and the ore partakes of the nature of the type that is characteristic of the two classes of rocks. Limestone is present only in small quantity at the mine, but other areas of the rock occur north of Wright's Pond and in the valley of the brook draining Stag Pond, which lies 1.5 miles north of the mine.

The mine was first worked about 1850, and thereafter at intervals until 1870, yielding a large quantity of ore. It was again operated in 1880 for several months, during which time 1,200 tons of ore were removed.

The mine consists of two large openings and a number of small ones. There are reported to be two ore-bodies with their long axes inclined to one another at 45°, or possibly a single large one that curves to this extent. In the southern pit, about 200 yards south of the northern one, the strike of the deposit was north-northeast, while in the northern one it was northwest. At the surface the dip in each case was vertical, but at the bottom of the pits it became steep easterly. At the same time the ore-body diminished in width. The southern deposit as developed was 100 feet long, 25 feet wide and 30 feet deep. The northern one was 700 feet long and about the same width and depth as the southern one.

At a point 100 yards south of the southern opening a smaller deposit was encountered, which yielded some good ore. West of the north pit several openings disclosed only a garnetiferous ore that was of little value.

The geological conditions under which the ore exists at this mine are exceedingly complicated. The limestone is present in

small quantity only, but it is of the same character as the altered phases of this rock elsewhere. The ore in the main bears a close resemblance to that at the Sulphur Hill mine, and probably had a similar origin. A section across the north end of the north excavation as it existed in 1855 showed: (a) compact ore containing pyrite at the east side of the ore-body, (b) a horse of rock composed principally of calcite, hornblende, magnetite and talc, (c) a granular ore on the west side of the horse. Gneiss occurred on the east side of (a) and the west of (c).

Analysis of the ore mined in 1868 gave:

Fe_3O_4	*S*	*P_2O_5*	*SiO_2 and ins.*	*Met. iron*	*Authority*
69.9.	.4	0	23.5	50.6	N. J. 1868, p. 629.

A pile of sorted ore taken from a lot of 50 tons awaiting shipment in 1880 gave:

Fe	*S*	*P*	*Authority*
53.92	.013	.035	10th Census, p. 151.

The total production of the mine to 1880 was 67,000 tons.

References: N. J. 1855, pp. 169–174; 1868, pp. 628–629; 1873, p. 88; 1880, p. 118; 1883, p. 145; 10th Census, p. 151.

(21) The Sterling Hill or Franklinite Mine.

This mine was first opened in 1877 at the southwest end of the zinc vein in Sterling Hill, Sparta Township, Sussex County. It was worked five years and then closed because of the increasing quantity of zinc minerals encountered.

The deposit mined was a phase of the franklinite zinc ore, in which franklinite had replaced nearly all the other minerals in the usual aggregate of franklinite, willemite and zincite. In appearance the material was a massive franklinite. The vein was 100 feet wide in some places, but it was very irregular in width. It consisted of a franklinite mass between deposits of willemite, the whole lying in the Franklin limestone.

The ore was reached by an adit 317 feet long that ran from the roadside, near the eastern foot of the hill, a northwest course, through limestone to the vein. The southeast wall was vertical, and near this wall, as well as at the end of the adit along the

northwest wall, were large bodies of zinc ore. On the surface an opening 225 feet long and 160 feet wide uncovered a very large quantity of ore.

As the hill was penetrated the franklinite became less massive and passed into a mixture of franklinite crystals disseminated through a calcite matrix.

Analyses of the ore first mined gave:

	Fe	*Mn*	*Zn*	*SiO_2 and ins.*	*Authority.*
I.	51.98	7.40	3.15	7.70	N. J. 1877, p. 52
II.	51.21	7.40	6.24	9.80	N. J. 1877, p. 52

I. Ore from near southwest end of deposit.
II. Ore from further northeast, within the deposit.

During the first two years of its life the mine yielded 45,000 tons of iron ore; 3,000 tons of zinc silicates, and 1,500 tons of material that was marketed as franklinite. The iron ore was used for Bessemer metal up to 20 per cent. of the total charge of the furnace.

References: N. J. 1877, p. 52; 1879, pp. 87–88; 1880, p. 118; 1883, p. 146.

(22) The Pike's Peak and Furnace Mines.

There are two mines that have at one time or another passed under the name of the Pike's Peak mine. One was near Split Rock Pond and was better known as the Stony Brook mine. The other was at Franklin Furnace in Hardyston Township, Sussex County. It was known also as the Franklin Iron mine. It is the latter that is referred to in the following paragraphs.

Near the zinc mines at Franklin Furnace are two magnetite veins that have from time to time been worked. One, in gneiss, near the contact between this rock and Franklin limestone, is designated the Hill vein (see page 255), and the other within the limestone is called the Furnace or Pike's Peak vein. The latter passes under the old charcoal furnace and continues to the northeast bank of the Wallkill River, where it was mined. From this point it runs southwest with a few interruptions parallel to the vein in the gneiss and only a few feet from it, the contact of the gneiss and limestone being between the two. The total length

of the mineralized zone is about 1.25 miles. The vein in the limestone was from 3 feet to 8 feet thick. It was first mined on the northeast side of the Wallkill River before 1855. In 1868 it was opened under the old charcoal furnace on the southwest side of the river, where it was very wide, and at several other points on the hill further southwest (Furnace mine), and later by a slope on the northeast side of the Wallkill River (Pike's Peak mine). This mine was worked almost continuously until 1881.

The principal opening in 1880 was on the hill north of the Wallkill River, and but a few rods distant from the zinc vein. It was a slope 300 feet long at an angle of 60°. The ore mass was in the form of three shoots, one above the other, and all pitching northeast and dipping 55° southeast. The ore was being taken from the 100-foot level, where it was concentrated in two bands, the centers of which were 5 feet apart. These graded off into limestone on both sides. Where the ore was lean the magnetite was arranged in the limestone in layers parallel with the trend of the deposit. The total width of the vein was 8 feet, of which about 4 feet was regarded as ore.

Explorations by diamond drill having revealed no shoots beneath the Furnace mine, this mine was abandoned in 1881.

Southwest of the Furnace mine, near the old flux quarry, a third vein was found about 100 feet east of that in the gneiss, but the body of ore was not sufficiently large to mine.

During the census year 8,960 tons were produced. It was used in the manufacture of Bessemer metal. The ore contained graphite, manganese and calcite. An analysis of an average specimen made in 1868 gave:

Fe_3O_4	*MnO*	*CaO*	*MgO*	*$CaCO_3$*	*C*	*P_2O_5*	*S*	*H_2O*	*Total*	*Authority.*
79.0	3.5	4.2	3.9	7.6	.6	0	0	.4	=99.2	N. J. 1868, p. 659

A sample taken from a pile of 150 tons in 1880 yielded:

Fe_3O_4	*MnO*	*S*	*P*	*H_2O*	*Insol*	*Authority.*
45.12	2.90	.439	.033	.24	2.41	10th Census, p. 154.

A complete analysis of this sample will be found on page 111.

Spencer, in his description of the magnetite veins at this place, remarks that:

"A feature of interest concerning the iron veins is their attitude in reference to the zinc deposit in Mine Hill. The outcrop of the zinc ore forms a bow or hook convex toward the southwest, the two legs of the vein or ore stratum dipping together to form a keel, which pitches to the northeast. The outcrop of the iron vein is parallel to that of the west leg of the zinc vein of Mine Hill, but from the turn of the latter the two diverge and the iron vein keeps a nearly straight course to the southwest, with the same trend as the boundary between the white limestone and the gneiss. The pitch of the iron ore shoots is in the same direction as the pitch of the keel forming the bottom of the zinc-ore deposit."

References: N. J. 1868, pp. 658–659; 1873, p. 88; 1879, pp. 88–89; 1880, pp. 118–119; 10th Census, pp. 153–154; 1883, p. 146; Folio No. 161, U. S. G. S., pp. 22–23; Geol. Atlas of N. J. Folio No. 2, pp. 22–23.

(23) The Split Rock Pond Mine.

The Split Rock Pond mine is at the north end of Split Rock Pond, in Rockaway Township, Morris County.

The mine is an old one, the early history of which is unknown. It was reopened in 1873 and worked during a portion of 1875, during which time a shaft 100 feet deep was sunk. The mine was then closed until 1878, when it was again reopened and operated during the succeeding two years. In the census year 1879-1880 about 560 tons were raised.

During this period two leads were developed by a shaft 100 feet deep. They were 50 feet apart. The eastern one was more than 14 feet across, 7 of which, toward the foot wall, consisted of alternate strings of granular ore and mica. The foot-wall or west "vein" contained a shoot of rich ore 25 feet high and 8 feet wide. Nothing is said in any of the reports upon the mine as to the existence of limestone in it, although great fragments of this rock impregnated with magnetite are still to be found on its dumps.

North of the shaft, near the Charlotteburg road, and for a distance of about a mile along this road, a number of pits were dug, and in almost all of these ore was found. The most northerly of these openings was later developed as the Wood mine. The ore is stated to have been used in making Bessemer pig.

An analysis reported in 1879 showed it to contain a very little phosphorus.

Fe = 63.399; *P* = 0.0109; *S* = 0.068; *Ti* = .00; Authority, N. J. 1879, p. 58.

On the east side of the lake an ore body was uncovered in 1872 which is nearly in the line of strike of the Hibernia lead. The Split Rock Pond mines are thus in a lead that is west of the Hibernia lead.

References: N. J. 1873, pp. 47–48; 1874, p. 23; 1879, pp. 57–58; 1880, p. 108; 10th Census, p. 174; N. J. 1883, p. 118; 1884, p. 91.

CHAPTER XI.

DESCRIPTION OF MAGNETITE MINES IN GNEISS.

CONTENTS.

The ores occurring in the gneisses are by far the most important, from a commercial point of view, of any classes of ore in the State. Nearly all the important mines of the Highlands have drawn their supplies from them, and all of the more permanent mines are situated in gneiss areas.

For convenience in describing them, the mines that have wrought on the deposits in the gneiss have been divided into a number of groups, each comprising a series of openings arranged in zones, or belts, trending with the strike of the gneisses, and separated from one another by zones of country rock from which mines are absent or over which a few openings are scattered irregularly. Each of the productive belts has been called by the name of some important mine situated thereon. The belts are described in order, beginning at the west, and the mines on each are discussed in succession, beginning with the southwesternmost. The advantage of this method of treatment over all others lies in the fact that mines that work the same vein or the same series of parallel veins are dealt with in sequence, and in this way the relations of their ore bodies to one another may be the better brought out. For some purposes a geographical order might be more desirable, but since this, in many instances, would destroy the geological continuity of the descriptions, it has been thought best to follow the order as indicated above.

MINES IN THE JENNY JUMP BELT.

The Jenny Jump belt of mines begins a short distance south of Belvidere, runs northeast through Oxford Church and along the east side of the main ridge of Jenny Jump Mountain, and terminates at its northeast end.

There have been a number of openings made on the belt, but only one—the Kishpaugh mine—has ever become prominent. The others were mainly explorations, though a few shipped a little ore, which in all cases was lean.

The Andover mine may also be considered as on this belt for the purpose of description, although it is on an ore body that may not be in the gneisses. (See page 79.)

(24) The Roseberry Mine.

The Roseberry mine was on the northwest slope of Scotts Mountain, about 1.5 miles south of Belvidere and 1 mile north-

east of the Schuler mine, in Oxford Township, Warren County, if the location indicated on the topographic map of the State is correct.[1]

Work began here in 1872 and was continued a year, during which time about 1,000 tons of ore were raised. Owing to the pinching of the vein to a width of only 6 inches the mine was closed. It was evidently opened again a few years later and worked until 1875, when it was again closed. In 1880 it was again reopened, and about 200 tons of ore were mined. It must have been again closed soon afterwards, as no reference is made to it in the reports of the State until 1890, when it is reported as being idle.

The ore was mixed with mica and a bluish shale, and consequently was lean.

References: N. J., 1873, p. 73; 1879, p. 82; 1880, p. 116; 1890, p. 53.

(25) *The Barton Mines.*

The Barton mines were on the east slope of the ridge south of Oxford Church, in Oxford Township, Warren County, on the west side of the road between Oxford Church and Little York.

The mine was opened before 1873, and two shafts 200 feet apart were sunk on a reddish-black granular ore. It was worked until 1876 or 1877, and quite a quantity of ore was raised. It was then closed.

The strike of the vein is N. 80° E., and its dip about vertical. The country rock, as seen on the dump, is interlayered with seams of magnetite and hornblende, and it contains lenses of ore sur-

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[1] Another mine of the same name was situated across the ridge in the valley of Buckhorn Creek. This produced limonite. From the fact that the ore of the mine referred to in the above paragraphs is said to have been mixed with a bluish shale it is possible that the mine here described and the one on Buckhorn Creek were the same, and that the location on the topographic map refers to an opening in magnetite which has not been described in any of the State reports. It is more probable, however, that the above description applies to the magnetite mine, the location of which is indicated on the map, as several old dumps in this vicinity give evidence of the former existence of a number of mine holes nearby, some of which evidently yielded considerable ore.

rounded by zones of hornblende. The ore is interlaminated with layers of biotite or some other dark mica.

References: N. J. 1873 p. 73; 1879, p. 82-83.

(26) The Kaiser Mine.

The Kaiser mine was about one-fourth of a mile southeast of Hazen P. O., in Oxford Township, Morris County, on the road between Oxford Church and Little York. The shaft was at the base of the hill a little north of east of the Barton mines.

The first explorations were made in 1882, but the ore body was lean and could not be successfully marketed without concentration. The mine was idle in 1890, but a concentrator was built and work was again started in the succeeding year. After operating a short time it was found that the project would not pay, and it was consequently abandoned.

The ore body was 11 feet thick, but only 5 feet was good ore. The product was concentrated to contain 65 per cent. of iron. The rock associated with the ore is a massive Pochuck gneiss interbanded with layers of a dark micaceous rock full of garnets.

References: N. J. 1882, p. 73; 1890, p. 53; 1891, p. 235.

(27) The Shoemaker Farm Exploration.

The Shoemaker farm exploration was three-fourths of a mile northeast of Oxford Church, in Oxford Township, Warren County.

A shaft sunk in 1872 discovered a wide belt of rock cut by parallel bands of magnetite too lean to work. It was therefore abandoned.

The location of the shaft has not been identified.

References: N. J. 1873, p. 74; 1879, p. 83.

(28) The Brewer Mine.

The Brewer mine was a shaft near the contact of the Franklin limestone and the gneiss, on the north side of the road, between Oxford Church and Pequest Furnace.

Nothing is known of the history of the pit. Its dump contains some very lean ore and a great deal of pegmatite. It is probable that no ore was ever shipped from it.

Pit East of Greens Pond.

A small pit on the east slope of the hill east of Greens Pond, in Hope Township, Warren County, is in a very massive Pochuck gneiss. So far as can be judged from its dump the material obtained from the hole was a magnetitic phase of the gneiss, too lean to be utilized as an ore.

(30) The Kishpaugh and (29) Cook Farm Mines.

These two mines were in the same deposit in Hope Township, Warren County, on the east slope of Jenny Jump Mountain, about 2 miles northwest of Danville. These and the other mines on the Jenny Jump belt are situated about one-fourth of a mile east of the belt of mines in the Franklin limestone. (See page 213).

The Kishpaugh mine was opened in 1871, and during its comparatively short life it was one of the most productive mines in the State. It was worked almost without interruption from the day it was opened until its destruction by fire in 1900, yielding in all about 125,000 tons of ore.

At the surface when the mine was first opened the vein was 50 feet wide. With greater depth it diminished to 20 feet, and in some places to 8 feet. Toward the northeast the deposit gradually thinned to a foot in thickness. In all, the vein was traced for a length of 700 feet by development work, and later was shown to continue a considerable distance further southwest, where it was opened up by the Cook shaft.

The ore occurred in distinct shoots, pitching southwest, or in a direction opposite to that in which most of the ore bodies in the Highlands pitch, and dipping 35° southeast. In 1882 explorations were carried on to the northeast of the main shaft by a slope which disclosed the vein dipping 28° southeast and pitch-

ing 15° southwest. The shoot was 90 feet high and 18 feet wide, with a layer of exceptionally rich ore a foot thick on the footwall. A thin layer of ore penetrated the caprock, but it was not worked. With increasing depth the dip became steeper (38°-45° southeast). In 1884 the mine was sold to the owners of the adjoining Cook mine, and the two were thereafter operated together.

In 1881 a vertical shaft, later known as the Cook shaft, was sunk southwest of the main Kishpaugh vein, through a coarse basic gabbro-like rock. It was expected that the vein would be reached at 200 feet. In the following year, when the shaft had been sunk to this depth, a diamond drill hole was put in to the west from the bottom of the shaft for a distance of 103 feet without striking ore. A second drill hole, located 220 feet to the northeast of the shaft and 23 feet from the road, at a depth of 285 feet found ore and continued in it for 26 feet without striking the foot wall. Shortly afterward the shaft was closed. It was reopened in 1890 and was lowered to 350 feet, where it penetrated the Kishpaugh deposit through the cap rock. Here the ore was 25 feet wide. It dipped southeast at 38° and pitched southwest. A diamond drill was started 500 feet southwest of the shaft, and this encountered ore 400 feet from the surface. Drifting from the bottom of the shaft proved that the ore retained its thickness and direction as in the old workings. At this time the ore had been developed through a distance along its strike of 2,000 feet, and from about one-half of this distance the ore had been removed. In 1896 the mine was idle. Work was resumed in 1899 and about 3,000 tons of ore were raised, but this was not of as good quality as that produced at the old Kishpaugh workings, which contained 52 per cent. of iron after washing, and was low enough in phosphorus to pass the Bessemer limit. In the following year 2,000 tons had been raised, when the machinery was burned and the mine flooded. It was then permanently abandoned.

A notable feature of the deposit in this place, especially that of the old Kishpaugh openings, was the great depth to which the ore was disintegrated. Even at 100 feet in depth it was so soft that it needed only an occasional blast to fit it to be raised.

The ore was not very rich as first mined. It contained considerable mica and hornblende on the whole, but in some places it was free from rock. Here it showed prismatic partings at right angles to the walls. In the footwall side a thin layer was strongly pyritiferous.

A carefully selected sample of the shipping ore analyzed in 1873 (N. J. 1873, p. 83 gave):

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	P_2O_5	S	H_2O	Total.
21.80	9.00	40.32	17.97	4.37	4.03	.50	.32	.05	1.64	= 100
			Fe=54.25[1]			P=.128				

Samples collected by the agents of the 10th Census yielded:

	Fe	Mn	P	S	TiO_2
1—	49.68	..	.036	.755	..
2—	54.71	..	.036	.542	..

1.—Sample from 200 tons from northeast stopes.
2.—Sample from 100 tons from southwest stopes.

A sample from the Cook Farm shaft gave:

$Fe = 55.91$	$P = .037$		N. J., 1885, p. 106
$Fe = 48.516$	$P = .042$	$S = .93$	N. J., 1899, p. 160

References: N. J. 1873, pp. 82–84; 1879, pp. 83–84; 1880, p. 117; 10th Census, p. 149; 1881, p. 37; 1882, pp. 73–74; 1884, p. 107; 1885, p. 106; 1886, p. 145; 1890, p. 56; 1891, pp. 238–239; 1896, pp. 323–324; 1899, pp. 159–160; 1900, p. 205.

(31) *The Corliss Explorations.*

The Corliss explorations were on the land adjoining the Kishpaugh property on the northeast, in Independence Township, Warren County.

Explorations were begun in 1882, and a small quantity of surface ore was found. The place was not worked.

References: N. J. 1882, p. 74.

(32) *The Stiff Farm Exploration.*

The Stiff Farm explorations were west of the Welsh-Inshow explorations, on the west side of the road running along the east

[1] The percentage of metallic iron corresponding to the determination of FeO and Fe_2O_3 is 42.20 instead of 54.25 as recorded in the published analysis. The reason for the discrepancy is not known.

slope of Jenny Jump Mountain, in Hope Township, Warren County.

The openings were made in 1871 on a coarse pegmatite containing irregular strings and sheets of magnetite. Nothing was done here except to uncover the ore, after which the place was abandoned.

References: 1873, pp. 84-85; 1879, p. 84.

(33) The Potter Farm Exploration.

The Potter Farm exploration consists of a single shaft, that is described as having been sunk in the valley between Jenny Jump Mountain and a ridge bordering the Pequest meadows, in Independence Township, Warren County.

The shaft was 35 feet deep, penetrating an ore band 4 feet wide, in which the ore is reported to be like that at the Kishpaugh mine.

Nothing further is known of the locality, nor has the position of the shaft been identified with certainty. It was probably the shaft indicated as being one-third of a mile southwest of the Stinson mine.

References: N. J. 1873, p. 85; 1879, p. 84.

(34) The Garrison Farm Explorations.

The Garrison Farm explorations were about 1 mile northeast of the Potter explorations in Independence Township, Warren County.

The mine was first opened about 1858, and some ore was raised. Its quantity and quality, however, are unknown. The opening is described as being on the east slope of the mountain near a small brook. The place was never worked. Later, in 1881, a bed of ore was found in another opening, which was 15 feet wide on the surface. The attraction near by is fairly strong.

References: N. J. 1873, p. 85; 1879, p. 85; 1881, p. 37-38.

(35) *The Andover Mine.*

The Andover mine was about 1.75 mile north-northeast of Andover in Newton Township, Sussex County, on the east side of the road between Andover and Pinckneyville. Its history is outlined in another place (see page 79 and Fig. 4).

The mine produced both hematite and magnetite, principally the former. The magnetite came mainly from the northernmost parts of the opening, and from that afterwards known as the Sulphur Hill mine (which see).

While the ore of the Andover mine was mainly hematite, there seems to have been intermingled with some of it a notable quantity of magnetite, sufficient at all events to cause the mixture to be slightly magnetic. In the northern portion of the mine the magnetite appears to have been more abundant than in the southern parts.

Analyses of some of the ores rich in magnetite are (N. J. 1868, p. 653):

Fe	*MnO*	*S*	P_2O_5	SiO_2 *and ins.*
1—46.80	19.85	.0	tr	6.90
2—46.40	1.45	.0	.47	4.50
3—55.20	tr	.0	.51	12.15
4—64.65	.40	tr	.19	2.75
5—59.20	tr	.0	tr	7.70

1.—Blue ore from central portion of deposit.
2.—Magnetite from upper part of deposit in center of mine.
3.—Magnetite from "middle mine."
4.—From northeast end of large mine.
5.—From east end of mine.

Analyses of samples taken by the experts of the 10th Census gave:

Fe	*P*	*S*	*Mn*	TiO_2	*Authority*
1—62.31	.001	.059	..	..	10th Census, p. 151
2—63.62	.018	.057	..	..	10th Census, p. 151
3—41.66	.110	.071	..	..	10th Census, p. 151

1.—Sample from 3 feet wide vein in small opening on hill, east of north end of open pit.
2.—From old pillar near north end of pit.
3.—From small pit west of mine opening.

The total product of this mine and the Sulphur Hill mine to June, 1880, was estimated to be 400,000 tons.

Because of the considerable proportion of manganese in some of the ore the iron made from it was considered of excellent quality. Analyses of some of this metal are given in another place (page 82).

References: N. J. 1855, pp. 149-163; 1868, pp. 648-653; 1873, p. 88; 10th Census, pp. 151-153; Folio 161, U. S. G. S., p. 21; Geological Atlas of N. J., Folio 2, p. 21.

MINES IN THE OXFORD BELT.

The Oxford belt of mines extends from the southwest end of Scotts Mountain to the northeast terminus of the Pimple Hills at Franklin Furnace. The mines are not evenly distributed along the zone. Most of them are grouped about Oxford Furnace and Warrenville as centers, the rest being irregularly distributed along two lines about a mile apart. There is no evidence that the ore veins are continuous from mine to mine. On the contrary, it is very probable that the zone comprises a series of short, approximately parallel veins, separated from one another by barren rock, and that the greater number of the mines are on isolated deposits.

The mines and explorations that are considered as occurring in the Oxford belt are the Carter, the Oxford group, the Barker, the mines around Warrenville, those near Allamuchy Pond, the Hill Vein at Franklin Furnace, the Copperas mine and the Bird mine.

Moreover, there is a spur that leaves the main belt at Allamuchy Pond and extends south of west along Cat Swamp Mountain, across the Pequest Meadows and beyond through Pequest Furnace to an unnamed mine south of the Queen mine. In this belt are situated the two mines northwest of Warrenville (probably Haggerty's explorations), the Cummins mines, the Hoit mine and the Pequest mine and the unnamed mine on the south slope of the line south of the Queen mine. This belt has been called the Cat Swamp Mountain belt.

There are a few other explorations situated far to one side of the other of the belts of mines as described, but they are evidently on very small deposits, as they have not proven promising enough to warrant the building of shafts.

(36) The Carter Mine.

The Willever and Godfrey, or Carter, mine was 2.25 miles west of north of Stewartsville, in Harmony Township, Warren County, near the top of the southeast slope of one of the terminal ridges of Scotts Mountain.

The locality was explored in 1880 by a shaft 48 feet deep, which opened up a vein of ore 9 feet wide. About 500 tons of ore were mined during the first year and 9 carloads were shipped. The mine was shortly afterwards closed down.

References: N. J. 1880, pp. 113-125.

THE OXFORD MINES.

The Oxford mines comprise a group of openings which are distributed along several veins just south of the village of Oxford Furnace, in Oxford Township, Warren County. These openings have been known under different names at different times, the names often changing with the ownership. They may be divided into two sub-groups—the Washington mine, including the old Harrison and Clark mines, and the Oxford group proper, comprising the McKinley or Carwheel, or Slope No. 3, and the old Staley, Lanning, New and Welch mines.

Mining was first undertaken at this place about 165 years ago, when the first mines were opened to supply ore to the Oxford Furnace, which was put into operation in 1743. Since this time the district has been continuously productive except for a few short periods when the furnace was not being operated.

The early history of the district is not known. In 1840, however, Prof. Rogers called attention to the fact that an immense quantity of ore existed beneath the surface in at least two veins which he supposed to be divided here and there into several parallel branches. He reported also that the veins were crossed by two or three large faults, and mentioned that two of the lodes "sweep round a curve of almost semi-circular form." Not all of Rogers' observations have been substantiated; nevertheless, the district has always proved of special interest because of the varia-

tion in the direction exhibited by the different veins. These are described in Cook's report of 1868 as running in a north of west direction, but slightly diverging from one another. The map published with the report represents all the veins as curving. The Staley and New mine veins are indicated as being approximately parallel and pretty nearly perpendicular to the Harrison and Franklin veins. To the west of the Harrison vein is another, about 5 feet wide, that was not named. This is curved, with its concave side to the east. As mapped it looks as though it might represent the southeast prolongation of the Franklin vein, outcrops of the two apparently producing an S-shaped curve. Of the several veins named, the Franklin and its southern extension have never been worked. There were, however, sufficiently numerous openings upon them prior to 1868 to prove their existence.

It is not known what names were given to the older openings. In 1868 shafts were indicated as existing on the Staley, New mine, Carwheel and Lanning veins at Oxford Furnace and on the Harrison vein half a mile further west. At this time the Carwheel mine had been worked to a depth of 125 feet in places and through a length of 500 feet. The New mine was, however, the principal source of ore through a long period. It is not known when the shaft was begun, but in 1868 it is recorded that the ore had been removed for a distance of 700 feet to the depth of 140 feet. The Harrison mine, on the western vein, was opened in 1864. The Staley mine was probably one of the oldest in the group. It had been abandoned before 1868, but from it a large quantity of good ore is said to have been extracted. In the course of time several of these mines were closed and several others were opened, but, as a matter of fact, the closing and opening was merely a migration of shafts along the same developed veins. The Harrison mine, for instance, was closed in 1876 and the Washington mine opened on the same vein in 1879. The Carwheel and New mines were abandoned in 1880 or 1881 and the McKinley mine opened in 1883. This in turn was abandoned in 1904 and a new shaft further east was opened in 1909. Throughout nearly the entire period of iron ore mining in New Jersey one or another of the Oxford shafts has been

active. Only during short periods of extreme depression has work entirely ceased. The principal contributors to the ore production in recent years have been the Washington and the McKinley mines.

The Franklin vein was never worked to any considerable extent, though an analysis of its ore reported in 1868, if representative of the whole deposit, shows that it possesses considerable value. The fact that the analyst reported no phosphorus, however, tends to make one skeptical of accepting his figures for the other components.

The analysis follows:

Fe_3O_4	*S*	*P_2O_5*	*SiO_2 and ins.*	*Metal. iron.*	*Authority.*
82.3	.1	.0	16.3	59.6	N. J. 1868, p. 639.

References: N. J. 1840, pp. 35-6, and citations under the respective mines of the group.

(37) *The Harrison and Washington Mines.*

These two mines were on the western vein, as delineated on the map of 1868. This vein consists of two parallel seams separated by 12 feet of rock. On one of these was the Harrison shaft, and on the other the Washington mine.

The former in 1868 had been worked for a depth of 94 feet and through a length of 250 feet along a deposit 12 feet thick. The ore was, however, very sulphurous, and as a consequence the mine was not working. At the Washington shaft, which was originally opened in 1854, ore had been removed from 663 feet of a deposit 18 feet thick to a depth of 100 feet. This mine, too, was idle in 1868 because of the great quantity of sulphur in the ore. The vein, however, had been traced for a distance of 2,100 feet, which later was increased to 4,000 feet. In 1879 work was resumed, an old slope west of the highway was reopened, kilns were constructed for roasting the ore, and a new shaft was sunk about 1,000 feet further south as a result of the excellent magnetic survey undertaken by W. H. Scranton (see Plate I, page 200), which developed a long and regular ore deposit that had an average thickness of 11 feet. Its strike was about 25° west of north, and its dip 45° to the southwest. The pitch is supposed

to be to the southeast, but the deposit is so uniform in thickness that no pinches have been recognized in it that are distinct enough to furnish satisfactory evidence on this point.

The mine continued in operation until 1885, when it was temporarily closed. It was soon afterward reopened and was operated until it was again closed in 1895, because of the failure of the Oxford Iron and Nail Co., by whom it had been worked. In 1900 it was again reopened, and since this time has been operated continuously. The construction of a new three-compartment slope was begun in 1901 at a distance of 1,400 feet south of the old one. This was completed in 1903 to a depth of 497 feet. A plan and a longitudinal section of this slope are shown in Plate II. In this year the mine produced 30,172 tons. The annual production at present is at the rate of about 100,000 tons per year.

Analyses of the ore from the Washington mine are as follows:

Fe	*S*	*P*	*SiO_2*	*Mn and TiO_2*	*Authority.*
1—57.43	.620	.505		....	10th Census, p. 161
2—61.36	.609	.657		....	10th Census, p. 161
63.19	1.68	.615	7.985		N. J. 1885, p. 106

1.—Sample taken across stope.
2.—Sample of 75 tons at furnace after removing lumps containing large quantities of pyrite.

An analysis of roasted ore produced in 1899 gave:

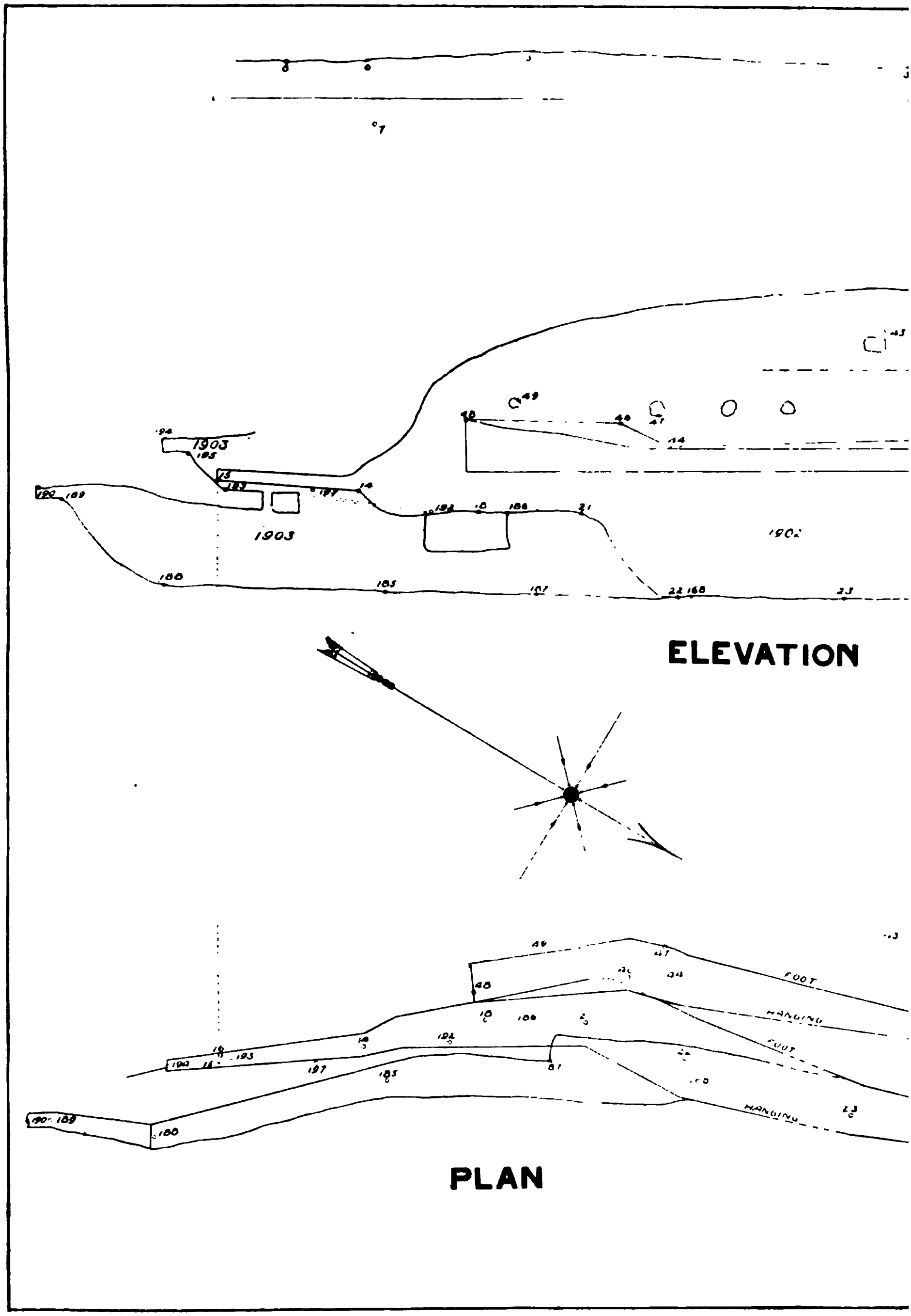
SiO_2	*Fe_3O_4*	*Al_2O_3*	*MnO*	*CaO*	*MgO*	*SO_3*	*P_2O_5*	*TiO_2*	*Total*	*Authority.*
10.18	82.22	1.90	.14	2.86	.85	.75	.98	.17	= 100.05	N. J. 1903, p. 99

The walls of the vein are a coarse magnetic hornblendic pegmatite, and the same rock occurs with the ore.

References: N. J. 1868, pp. 637-640; 1879, pp. 74 & 96-98; 10th Census, p. 161; N. J. 1883, p. 133; 1884, p. 101; 1885, p. 106; 1890, pp. 55-56; 1891, p. 238; 1896, pp. 322-323; 1900, p. 204; 1901, p. 136; 1902, pp. 117-118; 1903, p. 99; 1904, p. 294; 1905, p. 317; 1906, pp. 175-176.

(38) The Lanning Mine.

The Lanning mine was the southernmost of the Oxford openings. The shaft was situated on the upper slope of the ridge overlooking the village of Oxford Furnace, and on the west side of the road to Washington, some distance south of the McKinley mine.


1903
1903
1902
ELEVATION
FOOT
HANGING
FOOT
HANGING
PLAN

There were reported to be two magnetic lines intersecting on the property, and several pits in the vicinity of this intersection disclosed ore. The place was explored about 1873 without success. About seven years later the explorations were resumed, and what was regarded as a fine ore body was discovered in 1881. This was worked for two years, yielding about 12,000 tons of ore, and was then abandoned. The deposit, which was 150 feet long and from 2 to 15 feet wide, seems to have been an isolated one.

South of the shaft, at the Chapin and Lomassen explorations, a great deal of work was done in search of ore to explain the existence of a line of magnetic attraction, but without success. A small vein of ore was uncovered, but it was not large enough to warrant working. Its strike was east-west and its dip north.

Still further south, on the southeast slope of the mountain, near where the road to Washington passes down into the valley between Scotts Mountain and Pohatcong Mountain, several tunnels and a number of pits were dug in another area of rather strong attraction, but nothing of value was discovered.

An average sample of the Lanning ore obtained in 1881 had the following composition:

Fe_3O_4	MnO	CaO	S	P	Ti	*Authority.*
73.61	.635	4.82	.265	.00	.00	N. J. 1881, p. 37

References: N. J. 1873, p. 60; 1879, p. 74; 1881, p. 37; 1883, pp. 132-133; 1884, p. 101.

(40) The Carwheel and (41) New Mines.

The New mine was the principal source of ore for Oxford Furnace during the middle of the last century. In 1868 it had been worked for a distance of 700 feet along a deposit that varied in width from 18 to 40 feet and to a depth of 140 feet.

The Carwheel shaft was on a separate vein from the New mine shaft, but very close to it. The western end of the vein was worked during the latter portion of the 18th century by open pits, a large number of which were still visible in 1868. In this year it is reported that from the shaft the ore had been removed for a distance along the vein 500 feet, and at some

places to a depth of 125 feet. Both mines were operated until 1880 or 1881, when they were closed, the ore remaining in the shoots being more conveniently reached from the Welch and the Slope No. 3 openings. During their operation the two shafts together produced on an average about 25,000 tons annually.

The two veins were originally supposed to be connected, with the Carwheel vein occurring as an offshoot of the New mine vein. Later operations, however, proved that both shafts were working on two different deposits, consisting of two parallel curved shoots (Fig. 14). That in which the Carwheel shaft was sunk

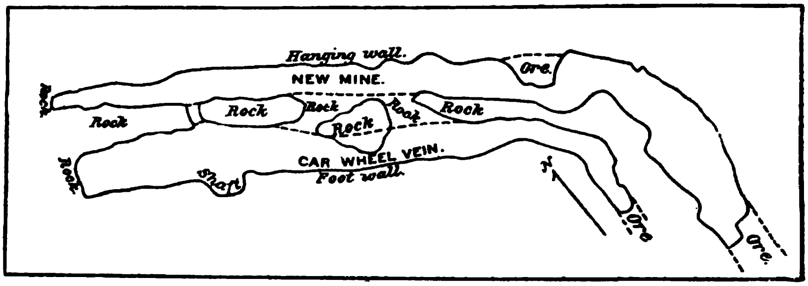


Fig. 14.

Plan of the ore-bodies at the New mine near Oxford Furnace, New Jersey. From surveys by Mr. William H. Scranton. (From Tenth Census Report, Vol. XV., p. 160.)

was on the southwest, and therefore below the deposit penetrated by the New mine shaft, since both dip northeast. The pitch of both was steep to the southeast. The strike in their most thoroughly developed portions is northwest, but at their northwest ends it is reported that they bend northward until they finally assume the northeast direction, which is the usual direction elsewhere in the Highlands, and connect with the vein at the Staley mine.

In mining no distinction was made between the ore of the two veins, although it was recognized that the material raised came from two distinct deposits. That in the New Mine was known as the "Carwheel" or "red-ore" vein and the "New mine" or "gray-ore" vein.

In the Welch shaft, which was 400 feet northwest of the New mine shaft, the two veins were called the "Welch" and the

"Slope" veins. Although the deposits reached by the two shafts were not continuous, being separated from one another by a mass of pegmatite and possibly by a fault, it was thought by those who were most competent to judge at the time the mines were working that the "Slope" vein was the extension of the "Carwheel" and the "Welch" the continuation of the "New mine" vein.

The New mine shaft was sunk near the foot wall of the Carwheel vein. When abandoned it was about 250 feet deep. At this depth the Carwheel deposit was only 4 feet wide. The New mine deposit still maintained its average width of 20 feet, but its bottom rock was probably not far beneath, and the ore was pretty lean (see analysis).

The ore from the Carwheel vein was a finely granular to compact magnetite, possessing a purplish tinge. That of the New mine deposit had a gray-black color. The former was used in the manufacture of carwheel iron, and hence the name of the mine.

The New mine ore was exceptionally free from sulphur, that from many of the stopes being of Bessemer grade.

Analyses follow:

Fe_2O_3	*MnO*	*CaO*	*S*	P_2O_5	TiO_2	*Insol.*	*Total*	*Authority*
95.08[1]	.30	.31	.10	.03	.00	7.32	=103.14[1]	N. J. 1873, p. 61

	Fe	*P*	*S*	*Mn*	TiO_2	*Authority*
1.—	39.54	.044	.758	....	....	10th Census, p. 160
2.—	54.84	.151	.225	....	....	10th Census, p. 160
3.—	43.31	.072	.307	....	....	10th Census, p. 160
4.—	46.66	.095	.270	....		10th Census, p. 160

1.—Hand-cobbed ore from New mine vein.
2.—Sample from Carwheel mine.
3.—Mixture of ore from the two veins. From a pile of 75 tons at Oxford Furnace.
4.—Sample from week's output of New mine, including ore from both veins.

References: N. J. 1868, p. 639; 1873, p. 61; 1879, p. 74; 10th Census, pp. 159-60; N. J. 1883, p. 133; 1884, p. 101.

(39) The McKinley Mine or Slope No. 3.

Slope No. 3 was on the Carwheel vein, about 400 feet southwest of the Carwheel shaft.

[1] Had the iron been calculated as Fe_3O_4 the corresponding figures would have been 92.23 and the total 100.29.

It was opened in 1883, and so far as known was worked practically continuously until 1895, when it was closed on account of the failure of its operators. It was reopened in 1899 and operated uninterruptedly until 1905, when it was abandoned.

When reopened in 1899 the workings were 700 feet long and 500 feet in depth, measured vertically. In its western part the deposit was 4 feet wide, and at its end its width measured 10 feet.

Because of the crookedness of the old slope a new one was sunk in 1902 about 125 feet south of the old slope. This was designated the McKinley mine. It encountered the old workings at a depth of 186 feet. The total depth of the shaft was 615 feet. The deposit at its bottom had a north-south strike and a dip of 56° east. Near the surface the dip was 45° east and the pitch 34° north. The walls were very irregular, and the ore was so mixed with rock that careful hand-cobbing was necessary to raise its metallic contents to 53 per cent.

Through this the ore was raised until operations ceased in the early part of the year 1905. Plans and sections of Slope No. 3 and the McKinley mine are reproduced in Plate III, the originals having been furnished by the Empire Steel and Iron Company.

An analysis of the ore raised in 1903 gave:

Iron oxide	Al_2O_3	*CaO*	*MgO*	*Mn*	*P*	*S*	*Ti*	SiO_2	*Authority*
70.78	2.04	7.54	2.98	.22	.23	.15	.36	14.84	N. J. 1903, p. 100

In 1901 a shaft was begun about 1,000 feet south of the McKinley mine, and this was given the name of Prospect No. 4. This appears to be on a vein that is entirely distinct from the two worked at the McKinley mine, but its relation to these has not been determined. It is proposed to operate this shaft in the near future.

References: N. J. 1884, p. 101; 1885, pp. 105–106; 1890, p. 55; 1891, p. 238; 1896, pp. 322–323; 1899, p. 159; 1900, p. 204; 1901, p. 137; 1902, pp. 117–118; 1903, pp. 99–100; 1904, p. 294.

(42) The Welch Mine.

The Welch mine shaft was situated about 400 feet northwest of the New mine shaft. It obtained ore from two deposits that lay side by side—the southwestern being known as the "slope"

vein and the northeastern as the "Welch" vein. These were supposed to be the continuation of the "Carwheel" and the "New mine" veins that were developed in the old mines of these names, and which were terminated a little northwest of the old shafts by a fault or a dike of pegmatite. (See description of Carwheel and New mines.)

It is not known when the shaft was opened. It was at work in 1880, but was obtaining ore from the Welch vein only, and this was much mixed with rock.

Samples of ore assayed in 1879 showed .05 per cent. of phosphorus. Analyses made by the chemists of the 10th Census yielded:

	Fe	*S*	*P*	*Mn*	TiO_2	*Authority*
1—	46.59	.342	.077	..	..	10th Census, p. 161
2—	41.60	.585	.059			10th Census, p. 161

1.—Sample of 100 tons at Oxford Furnace.
2.—Samples of a week's output. All from the Welch vein.

References: N. J. 1879, p. 74; 10th Census, pp. 159-160.

(43) The Staley Mine.

The Staley (or Straley) mine was one of the oldest of the Oxford group. It was situated on the road leading from Oxford Furnace to Washington, and operated on the northeasternmost vein. It was worked extensively before 1868, yielding an ore that was excellently adapted for the manufacture of bars. It had been abandoned before this date.

There is very little known about the ore. It is reported to have contained 0.16 per cent. of phosphorus.

References: N. J. 1868, p. 639; 1879, p. 74; 10th Census, p. 159.

OTHER MINES IN THIS BELT.

The other mines in this belt are of little importance. With few exceptions they are scarcely more than explorations. The country in the neighborhood of Warrenville and Allamuchy is honeycombed with pits and tunnels that were excavated in the

search for ore, but in neither district have any promising deposits been discovered.

(44) The Barker Mine.

The Barker or Bulgin mine was 6.5 miles northeast of Oxford Furnace, in Independence Township, Warren County, about one-half mile south of Vienna, on the west slope of Pohatcong Mountain.

A line of attraction runs up the hill to the southeast and under it was found a mass of ore 12 feet wide dipping 38° northeast. At the northwest end of the opening which was made in 1880 a northeast-southwest fault crosses the deposit and cuts it off. In the pit the ore was exposed for a distance of 20 feet in a vein striking northwest. The ore was fine-grained, rich and contained a mere trace of sulphur. Specimens seen in the dump are definitely interbanded with rock.

Several hundred tons of ore were raised in 1880, and from this a sample was taken which analyzed:

Fe_3O_4	MnO	S	P_2O_5	TiO_2	*Insol.*	*Fe*
85.56	.0	.0	tr	1.45	9.00	61.96

Another opening 300 feet further northeast also disclosed good ore, and attractions southwest of the main opening indicate the presence of other veins. These lines, together with the veins that have been uncovered, strike in a notably different direction from that usually followed by the ore veins in the gneisses.

The place appears never to have been worked.

References: N. J. 1880, pp. 114 and 125-126.

The Warrenville Group.

Beyond the Barker mine to the northeast are no other mines or explorations until the village of Warrenville, in Allamuchy Township, Warren County, is reached, which is distant about 4.5 miles from the Barker mine. In the vicinity of this village, however, there has been a persistent search for ore deposits, which on the whole have been unsuccessful. A large number of pits have

been dug, a few shafts sunk and some tunnels and drifts driven, but only a few small ore bodies have been uncovered. The country is strongly mineralized, but the magnetite is apparently well scattered through the rock in sufficient quantity to affect the magnetic needle to an appreciable degree, but is not concentrated in large enough deposits, so far as the present indications show, to warrant the construction of mining plants. A little ore has been raised from some of the pits, but most of these have not risen above the dignity of mere explorations.

Most of the explorations were made before 1868, and practically all had been abandoned by that time. Although many of the pits and shafts are still easily visible, nevertheless it is impossible to identify them under the names that are used in the early State reports. This, however, is a matter of no great practical importance at the present time, because none of the explorations gave promise of the presence of ore deposits of any considerable size.

Most of the pits are on the west side of the road from Warrenville to Hackettstown and within 1.5 miles of the village. Among the most important openings west and south of Warrenville may be mentioned the Hamilton, the Axford Farm, the Maring Farm, the Frace, the Pyles Farm and the Young Farm explorations. North of Warrenville, on the west side of the road to Allamuchy, were other explorations, known as the Haggerty Farm explorations. An exploration on the farm of Henry Barkman was southeast of Warrenville, on the road across the mountain. In only a few cases is it known when the openings were made.

(45) The Hamilton and Barkman explorations were undertaken before 1868. The former consisted of a shaft 20 feet deep located on the summit of a hill. It penetrated a very irregular deposit consisting of a mixture of pyrrhotite, pyrite, a little magnetite, considerable apatite, and hornblende. The hornblende and pyrite are enclosed in the pyrrhotite. Of course the deposit was of no economic value.

The Barkman exploration was an old one when described in the Report of 1868. It is not known whether the small quantity of ore taken from the hole was obtained from boulders or from a small deposit.

(46) The Maring Farm explorations were half a mile southwest of Warrenville. Openings on a long and continuous line of attraction disclosed some good ore. Southeast of this line the vein of the Livesey or Hibler mine, at Allamuchy Pond, can be traced by its outcrop across the property nearly a mile. So far as is known no ore was ever shipped from this place.

A number of other explorations were started about 1871 in the neighborhod of the village, but so far as known none proved productive of ore. Very few of them can now be identified, although pits are numerous in the country southwest of the village. Only the most important of these need be referred to.

The Axford Farm explorations, like most of the others, were on the west side of the road leading to Hackettstown and between the two roads running west to Petersburg. A small quantity of ore was found here, but the vein was too narrow to work profitably.

(47) The Frace Farm explorations were but a few rods distant from Pyle's openings. These were the most pretentious of this group of workings. Two shafts were sunk about 1871, one of which uncovered a lean ore and the other a very narrow vein of richer ore. Neither was of commercial value.

(48) The Young Farm exploration was near the opening on the Pyle farm. About 1871 a shaft was sunk on a line of attraction. This penetrated a dark-colored gneiss that contained a considerable quantity of magnetite, though not enough to warrant mining operations.

On a high ridge west of these pits a magnetite-bearing gneiss was again encountered, but it was valueless as a source of ore.

(49) The Pyle Farm explorations revealed the presence of a magnetiferous pegmatite crossing gneisses perpendicular to their foliation. No mining was attempted.

There was also some exploration undertaken on the brow of the rocky hill east of Warrenville, but ore was found in too small quantity to pay for working.

References: N. J. 1868, p. 625 (Barkman exploration); 1868, pp. 624-625 (Hamilton shaft); 1873, p. 87; 1879, p. 85 (Maring farm); 1873, p. 63 (Axford farm); 1873, p. 63; 1879, p. 76 (Pyle's farm); 1873, p. 63 (Young farm); 1873, p. 63 (Frace's farm).

(50) Haggerty's Diggings.

Haggerty's explorations were north of Warrenville on the west side of the road to Allamuchy.

A series of trenches across the banding of the gneisses uncovered a number of small veins and strings of ore, but nothing of any size. Later, about 1875, a shaft 40 feet deep was sunk into what was reported to be a good vein, but no mining was done.

References: N. J. 1873, pp. 87–88; 1879, p. 86.

Explorations near Allamuchy.

The magnetic lines west of Warrenville extend northeast toward Allamuchy, passing just west of Allamuchy Pond. Here they have been explored almost as energetically as in the vicinity of Warrenville and with the same unsatisfactory results. A number of small deposits of lean ore were exposed, but none of the discoveries were sufficiently promising to warrant systematic mining.

The most extensive explorations were carried out along the west side of the pond under the name of Livsey's or the Hibler Farm mine. Large dump-heaps of a fresh gabbroitic rock are still to be found at the north end of the lake by the side of the road to Allamuchy, but very little ore can be seen.

(51) The Livsey or Hibler Mine.

On the hill west of Allamuchy Pond, Warren County, about a dozen pits and shafts were sunk between 1868 and 1873. Some of them encountered a highly magnetiferous gneiss, dipping steeply southeast. This lean ore, which was a gneiss banded with thin layers of magnetite, gave on analysis:

Fe_3O_4	P_2O_5	*Silicates*	*Authority*
26.95	1.02	72.03	N. J. 1873, p. 87.

A few years later another vein was opened west of the first exploration. A shaft 70 feet deep struck an ore reported to be 7 or 8 feet wide, in which again ore and rock were intermingled

This proving unsatisfactory, in 1880 a tunnel was driven westward from the lake shore into the hill for the purpose of intercepting the veins which had been discovered on the surface. Although this penetrated the hill to the distance of 200 feet, no deposits were found that were worth working. The rock taken from the tunnel is a very black, massive phase of Pochuck gneiss.

In 1906 a sample of ore taken from near the surface in the neighborhood of these explorations was analyzed by the chemists of the Thomas Iron Co., showing:

$$Fe = 51.53 \qquad P = .12 \qquad S = .14$$

References: N. J. 1873, p. 87; 1879, pp. 85–86; 1880, pp. 117–118; 10th Census, p. 151.

Beyond Allamuchy there are no other developed deposits on this belt until its northern end is reached, 15 miles further to the northeast. Just west of Ogdensburg, on the east slope of the Pimple Hills, are the developments of the Stirling Hill zinc mines, one of whose openings furnished franklinite that for some time was utilized as an ore of iron. This, however, is in the Franklin limestone. About two and a half miles further northeast was the Hill mine, at Franklin Furnace. This was on one of the two parallel veins, of which one was in limestone (the Furnace or Pike's Peak vein, see page 227), and the other, the Hill vein in gneiss. The only other openings were the Copperas mine and Bird mine, 6 and 10 miles, respectively, beyond Franklin Furnace, on the west side of Pochuck Mountain, near the State line, and a few explorations at points not now easily determinable.

(52) The Losey Explorations.

The Losey explorations were in Hardyston Township, Sussex County, on a line of attraction in the valley of the Wallkill River, between Ogdensburg and Franklin Furnace.

The line, according to descriptions, passes from gneiss into limestone, and on both portions ore was found in 1881. The exact positions of the explorations are not known. They were probably on the Hill mine vein about 2,000 feet south of the southern pit of the Hill mine.

The ore in the limestone contained considerable calcite, and was known as light ore. That from the gneiss, known as "black ore," was of the usual character of the ore in the siliceous rocks.

An analysis of average samples of each follows:

	SiO_2	*Fe*	*Mn*	*S*	*P*	*Authority*
Light ore, ...	2.16	38.43	.625	.14	.028	N. J. 1881, p. 39
Black ore, ...	22.57	44.10	.48	1.64	.05	N. J. 1881, p. 39

References: N. J. 1881, p. 39.

(53) The Hill or Franklin Mine.

The Hill or Hill vein mine was on one of the two parallel magnetite deposits at Franklin Furnace, Hardyston Township, Sussex County. The mines on the deposits in the limestone were known as the Pike's Peak and Furnace mines. (See page 227.)

The vein in the Hill mine was opened for a distance of 1,800 feet along its length before 1868, and already at this time considerable ore had been removed from its southern end, on the hill, south of the furnace. The mine was not operated between 1868 and 1873. Later (in 1879), however, it was reopened southwest of the old openings and was worked extensively in 1879 and 1880. It was finally abandoned in 1882 because of its increasing leanness.

The vein can be traced southwest from the shaft of the Trotter (zinc) mine parallel to the zinc vein and only 40 or 50 feet from it across the Wallkill River and along the side of Mine Hill, for a distance of 1.25 miles. It is very near the contact between the gneiss and the Franklin limestone, and is in some places partly within the latter rock. Its dip is about 50° southeast, corresponding with the dip of the west leg of the Franklin zinc deposit. Much pegmatite is interbanded with the gneiss associated with the ore, and in a few places it cuts across the gneissic foliation. Allanite and magnetite are present in some of this pegmatite, and garnets of various colors occur in the limestone near the ore.

In 1880 the old shaft which was near the furnace had reached a depth of 190 feet and the deposit had become narrow. Operations were therefore transferred to a new opening some distance further to the southwest. This, however, was not used long,

since, as has been already stated, the place was abandoned in 1882.

The ore from this mine is reported to have been used in the manufacture of Bessemer pig, though it is difficult to understand how this could be, unless it was mixed with large quantities of other ores, as its analyses show a comparatively large percentage of phosphorus.

A sample taken from a point south of the furnace in 1868 (N. J. 1868, p. 658) gave:

Fe_3O_4	Al_2O_3	CaO	MgO	$K_2O.Na_2O$	P_2O_5	S	SiO_2	*Total.*
80.8	2.3	4.7	2.3	1.0	.6	0	10.4 =	101.2

Another sample taken by the officers of the 10th Census from a pile of 1,000 tons at the shaft yielded:

$Fe = 27.88$; $P = .045$; $S = .267$. Authority: 10th Census, p. 153.

The ore was shown by the mining operations to possess the usual shoot and pinch structure. It was a mixture of magnetite and hornblende.

During the census year the mine produced 6,720 tons.

References: N. J. 1868, pp. 658–659; 1873, p. 88; 1879, pp. 88–89; 1880, pp. 118–119; 10th Census, p. 153; 1883, p. 146; Folio No. 161, U. S. Geol. Survey, pp. 22–23; Geol. Atlas of N. J., No. 2, pp. 22–23.

The Greer Farm Tract.

Explorations for iron ore were made on a line of attraction on the Greer Farm tract, or Franklin Iron Company's property in Hardyston Township, Sussex County, but without success. The exact location of the exploration is not known.

References: N. J. 1879, p. 80.

(54) The Copperas or Green's Mine.

There have been two mines that have gone under the name of Copperas mine and two that have been called Green's mine in the reports of the New Jersey Geological Survey. The one here referred to was on the east side of Pochuck Mountain, in Vernon Township, Sussex County. The other Copperas mine was in

Rockaway Township, Morris County (see page 374), and the other Green's mine on Wawayanda Mountain in Vernon (page 310).

The present mine was about 1.5 miles north of McAfee on the east slope of Pochuck Mountain, near Decker Pond. It was opened early in the 19th century, and was abandoned about 1816. The ore was mainly pyrite or a magnetite very rich in the sulphide. It was originally worked for the purpose of obtaining material to be used in the manufacture of copperas.

References: N. J. 1855, p. 146; 1868, p. 660; 1873, p. 88; 1879, p. 89.

(55) The Bird Mine.

There have been several mines described by the name of Bird mine in the literature of New Jersey mines. One was a limonite mine, near Clinton, in Hunterdon County, and the other was a magnetite mine in Vernon Township, Sussex County, on the west side of Pochuck Mountain, about 4 miles north of the Copperas mine. The latter has not been worked since before 1868, and nothing is known about the quantity or quality of its ore.

References: N. J. 1868, p. 660; 1873, p. 88; 1879, p. 89.

MINES IN THE CAT SWAMP MOUNTAIN BELT.

The Cat Swamp Mountain belt of mines includes a number of independent explorations and mines situated along a line extending from the Pequest mine, near Pequest Furnace, to Allamuchy Pond, where it joins the Oxford belt. None of the openings upon it have proven of any great value, though the Pequest mine produced during its life a large quantity of lean ore.

The northeasternmost openings on the line were those known as Haggerty's explorations, which have already been described. The others are taken up in the order of their locations from southwest to northeast.

(56) The Pequest Mine.

The Pequest mine was in reality a great quarry on the south slope of Mount Mohepinoke, about three-fourths of a mile east

of Pequest Furnace, on the north side of the road between the furnace and Townsbury.

Ore was first discovered here in 1869, and during the following 3 years the mine was worked without interruption, and a large quantity of ore was removed. It was opened again later and worked until 1875. Work was again resumed in 1880 and the mine operated 5 months, when it was permanently closed, because of the exhaustion of the ore body. This was taken out to the bottom rock on the south and west sides of the opening.

The ore, which was lean, occurred in a large swollen shoot, underlain by a hornblende gneiss (Pochuck gneiss) dipping about 70° southeast. North of the shoot on the surface was a gray granite which ran east and west and dipped steep toward the north, cutting out the ore in that direction. This is regarded as a dike, which is thought to have displaced the vein. Tunnels and pits put down to the west and tunnels run in below the mine to intercept the continuation of the vein in these directions were unsuccessful.

The ore was largely a soft mixture of magnetite and decomposed hornblende, that was so lean as to require the smelting of 3.5 tons of ore to produce one ton of metal. It was practically a very magnetitic basic gneiss. An analysis of the richly magnetic portion of the ore yielded:

Fe_3O_4	*Ins.*	Al_2O_3	CaO	MgO	MnO	H_2O	P_2O_5	*Total*	*Fe.*
67.47	18.30	3.23	5.94	3.28	.25	1.95	tr	= 100.42[1]	48.84

References: N. J. 1873, pp. 76–78; 1879, p. 83; 1880, p. 116; 10th Census, p. 149.

(57) The Henry Tunnel.

At 300 yards northeast of the Pequest mine, in Oxford Township, Warren County, was an old tunnel, the mouth of which is about 150 feet above the Pequest River.

This was reopened about 1870 and extended to a distance of 650 feet northward into the hill, along the foot wall of a vein about 15 feet wide, dipping steadily to the east.

[1] Authority: N. J. 1873, p. 78.

A second tunnel about 50 feet below the first struck the vein at a greater depth, and at its northern end was connected with the upper tunnel by a shaft. A third drift starting near the foot of the hill ran across the rock structure at right angles to the upper two and entered the vein about 100 feet below the level of the uppermost tunnel. North of the upper tunnel trenches dug across the line of the vein succeeded in tracing it all the way to the Hoit mine, 1,500 feet distant from the tunnel opening.

The vein dipped uniformly and was similar in width and character at all points examined. The walls were regular and well defined. At the surface the ore was composed of alternating layers of magnetite and rock. At greater depths the thickness of the rock layers diminished and finally they disappeared, the ore becoming correspondingly richer.

An analysis of the lean surface ore gave:

Fe_3O_4	Al_2O_3	CaO	MgO	MnO	SiO_2	Ins.	P_2O_5	H_2O	Total	Authority
37.26	4.76	tr.	1.61	.40	49.40	5.00	.096	1.20	=99.726	N. J. 1873, p. 1879

So far as known the place was never worked.

References: N. J. 1873, pp. 78–79; 1879, p. 83; Trans Amer. Inst. Min. Eng., Vol. 2, pp. 73–74, and 317–318.

(58) The Hoit Mine.

The Hoit mine is near the top of Mt. Mohepinoke, and about 1 mile north of Pequest Furnace, in Oxford Township, Warren County.

The mine was first opened about 1870 by a slope on a vein dipping 30° southeast, but becoming steeper with depth. It was later drifted on in a southwest direction for 70 feet. The drift is described as presenting "the curious phenomenon of an arched roof with sides of ore, the vein dipping from it towards the southeast at the angle of the slope, and in the opposite direction more gently." The condition is explained as possibly due to the presence of an anticlinal fold or to a throw of the vein westward.

The ore is compact and banded. It contains irregular masses of garnet, besides considerable augite, quartz and other minerals common to the adjacent gneiss.

An analysis of the average run of the mine gave:

FeO	Fe_2O_3	Al_2O_3	CaO	MgO	MnO	SiO_2	P_2O_5	TiO_2	S	*Total.*
27.23	38.29	12.48	4.45	.86	.55	18.90	.06	1.30	1.23	= 105.25[1]

The ore is remarkable for containing garnet, which is rare in the New Jersey magnetites. The associated rocks are also abnormal. Instead of the usual gneiss of the district, the rock forming the walls of the ore body is a much sheared garnetiferous, quartzose schist, containing a considerable quantity of garnet and some sillimanite. It may represent an old sediment that has been metamorphosed by the surrounding gneisses.

The mine was probably worked until 1875, although no statement to this effect can be found in the literature.

References: N. J. 1873; p. 80; 1879, p. 83.

(59) *The Hoit Farm Explorations.*

The Hoit Farm explorations in Hope Township, Warren County, comprised a shaft about one-third mile northwest of the Hoit mine, and a series of old pits on a line of attraction northeast of the mine.

The exploration northwest of the mine consisted of a shaft which opened up a lean ore composed of magnetite and hornblende not worth working. In the northeast explorations a banded ore like that at the Henry tunnel was found, but this also was too lean to be mined with profit. The associated rock, like that at the Hoit mine, is a sheared garnetiferous gneiss.

References: N. J. 1873; pp. 79-81.

(60) *The Green Farm Exploration.*

The Green Farm exploration was on the east border of the Pequest Meadows, in Independence Township, Warren County. It was southwest of the Cummins mine, on the north slope of Cat Swamp Mountain, near its southwest end. It is probably identical with the Carroll place exploration referred to in the State Reports of 1879 and 1883.

[1] Total is given as 100.25 in original (N. J. 1873, p. 80).

A shaft 90 feet deep was sunk in 1882, and a vein of good quality ore 6 feet wide was found. Nothing further is known of the place.

References: N. J. 1879; p. 85; 1882, p. 74; 1883, p. 144.

(61) Scranton's Lease.

Scranton's lease exploration was reported as being about a mile northeast of Danville, in Independence Township, Warren County, on the east side of the Pequest Meadows.

A single pit is reported to have found a good vein of ore, but nothing further is known of the occurrence.

The location has not been identified. It was probably on the northwest side of Cat Swamp Mountain, a short distance southwest of the Cummins mine, and was possibly incorporated with this mine during the latter part of its history.

References: N. J. 1873, p. 87; 1879, p. 85; 1883, p. 144.

(62) The Cummins Mine.

The Cummings or Cummins mine consisted of a number of openings at the north base of Cat Swamp Mountain, in Independence Township, Warren County, about 4 miles west of Warrenville.

Before 1868 openings had been made on the southeast slope of the ridge near the Schaeffer farm explorations. Here the gneiss dip 70° to 80° southeast, and contain layers that are very rich in magnetite. In these it was hoped to find some ore. Explorations on the mountain, however, were not vigorously prosecuted until 1881 and during a portion of the succeeding year, when a new shaft was sunk in the ore on its north side. During the course of sinking about 400 tons of ore were removed. A cut near-by exposed a breadth of from 10 to 15 feet of ore, which was generally lean, but contained very rich streaks in places. The vein dipped steeply to the northwest, but became flatter with depth. In 1882 the yield was 20 tons daily of 40 per cent. ore. Work was suspended in the latter portion of this year after the

shaft had been sunk to a depth of 80 feet and 3,000 tons had been shipped. The ore carried garnet, pyrite and some other components. No regular walls had been found.

An average sample of the washed ore gave:

SiO_2	*Fe*	*Mn*	*S*	P_2O_5	TiO_2	*Authority.*
16.31	56.54	1.77	2.80	tr	.0	N. J. 1881, p. 38

A belt of attraction passes through the mine and extends for a long distance in both a northeast and southwest direction. Toward the east an opening made on the adjoining (63) Ayres property in 1881 also encountered ore of the same quality. This exploration is sometimes designated as the Ayres mine.

References: N. J. 1868, pp. 625-626; 1879, p. 85; 1881, p. 38; 1882, p. 74; 1883, p. 144.

(64) The Schaeffer Farm Explorations.

The Schaeffer or Shafer Farm explorations were 2.25 miles southwest of Warrenville, near the line between Independence and Allamuchy townships, Warren county, on the southeast slope of Cat Swamp Mountain.

The first exploration, made in 1872, uncovered a small vein of rich ore, which is reported to have soon pinched out. In 1880 explorations were resumed, and a shallow opening on a line of attraction discovered a fine-grained ore that analyzed:

Fe_3O_4	*MnO*	Al_2O_3	SiO_2	*Ins.*	P_2O_5	*S.*	TiO_2	*Total*	*Fe*	*P*
87.21	0	2.68	9.95	.50	.025	.05	.0 =	100.415	63.15	.011

References: N. J. 1873, p. 87; 1879, p. 85; 1880, p. 117 & 127–128.

MINES IN THE GAFFNEY MINE BELT.

The line of mines east of the Oxford belt begins near New Village, runs northeast near the east side of Scotts Mountain, through the center of Allamuchy Mountain, and along the west side of Hamburg Mountain to Vernon, where it ends.

The southern end of the line has not been productive. A number of pits have been put down on magnetite deposits, but none of them have proven of value. The ore appears to be lean and in small quantity. Further north the deposits have been more prom-

ising, but in no case have they resulted in the development of a large mine. In two cases operations were carried on continuously for several years, and a considerable quantity of ore was mined, but most of the openings never were more than explorations.

There are three pits on the south side of Scotts Mountain, all of which, judging from the size of their dumps, must be fairly deep. There is no reference to these in the literature, nor has any definite information about them been obtained from the persons living in their vicinity. One of the pits is 1 mile north of New Village, on the east side of the road to Montana; a second is a mile northeast of Brass Castle, on the road running northwest from Washington, and the third on the west side of the road between Washington and Oxford Furnace, and about midway between the two.

Probably none of these pits ever shipped any ore.

(65) Haggerty's Farm Explorations.

Haggerty's Farm explorations in Allamuchy Township, Warren County, were about 1.25 miles southeast of Warrenville on both sides of the road to Saxton Falls.

A long and broad band of attraction running northeast was explored in 1874. In a pit at the northern end of the exploration a distinct vein of ore was found that was rich near the hanging-wall, but which near the foot-wall was lean and much mixed with quartz, feldspar and hornblende. It was probably a magnetiferous pegmatite dike, but the openings were too shallow to afford much knowledge of the vein.

A commercial analysis of a few tons raised in 1874 gave:

$$Fe = 56.40;\ P = .21;\ \text{and}\ S = .05.$$

A later analysis (N. J. 1879, p. 76) gave:

$$Fe = 58.55;\ P = .33;\ S = .05;\ TiO_2 = 4.20.$$

About 100 tons of ore were mined.

References: 1876, p. 52; 1879, p. 76; 1884, p. 103.

(66) The Bryant Mine.

The Bryant mine was 1 mile southeast of Warrenville and about three-fourths of a mile from the Morris Canal, in Allamuchy Township, Warren County.

The place was first opened in 1866 by two shafts, but as only a rich magnetite-bearing pegmatite was encountered it was soon abandoned.

The exact location of the old shafts was not discovered. The exploration must have been very near the Haggerty Farm exploration.

References: N. J. 1873, pp. 63–64.

(67) The Waterloo or Brookfield Mine.

The Brookfield or Waterloo mine was on Allamuchy Mountain, in Allamuchy Township, Warren County, about 2.5 miles west of Waterloo and 1.5 miles southeast of the village of Allamuchy, in a valley between two ridges.

It had been worked to a slight depth before 1855 and abandoned after uncovering a seam of ore from 3 to 5 feet in thickness, which was separated into two parts by a horse of rock from 1 to 2 feet thick.

Three shafts were sunk before 1868, finding an ore vein with an average dip of 40° southeast. At the mouth of the principal shaft it was 4 feet wide, but it diminished to 1 foot a little further down. The wider band contained interlaminations of rock. In 1868 the mine was explored more thoroughly than had been the case previously, and a deposit 8 or 9 feet thick was opened up.

The mine was operated during the succeeding five years, producing many thousand tons of a superior ore. It was closed at the end of 1873, when the main shaft was 300 feet deep; but it was evidently reopened later, as it is reported as being in operation during 1884 on a vein 5 feet wide.

The ore analyzed:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Met Iron.	Authority.
90.4	5.2	.0	tr	65.5	N. J. 1868, p. 628

References: N. J. 1855, p. 163; 1868, pp. 626–628; 1873, pp. 64–65; 1879, p. 76; 1884, p. 103.

(68) French's Mine.

French's mine was west and northwest of Waterloo, in Byram Township, Sussex County.

About a thousand tons were mined before 1873, at which time the openings had been abandoned.

The ore was a coarse mixture of magnetite and feldspar, resembling a magnetitic pegmatite. The exact location of the openings has not been ascertained. They were probably just west of the pond, three-fourths of a mile northwest of Waterloo.

References: N. J. 1873, pp. 66–67; 1879, p. 77.

(69) The Silver Mine.

The Silver mine was in Byram Township, Sussex County, on the Sussex railroad, about a mile south of Cranberry Lake.

The principal opening, which was made before 1855, is 200 yards west of the railroad. The deposit is irregular in shape but quite large.

The ore consisted mainly of masses, seams and bunches of pyrrhotite intermingled with pyrite, magnetite and a dark-green mineral, possibly chlorite.

An analysis of the ore showed the presence of about 73 per cent. of iron sulphides.

Fe	*S*	*O and loss*	*SiO_2 and ins.*	*Authority*
54.2	34.4	24.0	7.4	N. J. 1868, p. 621

The deposit was never worked much.

References: N. J. 1855, p. 173; 1868, p. 621; 1873, p. 67; 1879, p. 79.

(70) The McKean Mine.

The McKean or Bird mine was situated about one mile northeast of Cranberry Lake, on the northwest side of the road to Roseville, in Byram Township, Sussex County.

The mine was first opened in 1873 by a shaft 40 feet deep and drifts 40 feet long. It was operated intermittently until 1880.

The vein where first discovered was 12 feet wide. From this about 1,200 tons of ore were removed. When operations ceased there were two shafts 200 feet north of the older openings and 100 feet apart, besides several pits. The depth was 90 feet.

The dip of the ore body was steep to the southeast. Its hanging wall was distinct, but at the foot wall there was gradation between ore and rock.

An analysis of the ore raised in 1874 gave:

Fe_3O_4	MnO	Al_2O_3	CaO	MgO	*Ins.*	*S*	*P*	*Ti*	*Total*	*Authority*
64.36	.30	3.50	.45	1.76	28.50	.22	.03	tr	= 99.12	N. J. 1874, p. 28

The total yield of the mine is reported to have been 4,000 tons.

References: N. J. 1874, pp. 28–29; 1879, p. 86; 1880, p. 118; 10th Census, p. 151; 1883, p. 145.

(71) The Bedell Mine.

The Bedell mine is about one-fourth of a mile south of the Gaffney mine, in Byram Township, Sussex County.

The mine is in an area of attraction which is distinct from that of the Gaffney mine. At one time the mine was of considerable importance, if one may judge from the size of its dumps. There are two shafts, which must have been worked in the 90's, and several pits. The rocks on the dumps are evenly banded dark Byram gneisses streaked with magnetite layers. They are gently folded, and in some instances are cut by branching veins of hornblende and magnetite.

Nothing has been learned of the history of the mine or of its economic importance. It is probable that the ore was lean. The attraction in the immediate vicinity of the mine holes is strong, but it dies out rapidly a short distance from them.

(72) The Gaffney Mine.

The Gaffney mine was 3.25 miles southwest of Sparta, about midway between this village and Roseville, in Byram Township, Sussex County.

The original openings at this place are old, but more recent openings date from 1874. The mine was worked for a few

years, but was closed in 1876. It was reopened in 1880, but was abandoned shortly afterwards.

A strong line of attraction extends for 800 feet northeast of the old pits, and at one point a short distance east of north of the openings the attraction is so strong that a map was prepared in 1873 to illustrate an essay dealing with the methods of exploring for magnetite. After being opened a vein 6 to 8 feet wide of good ore was developed.

Very little is known concerning the history of the operations. It is, however, evident that they were extensive from the large dump-heaps that were left, and the fragments of good ore that are scattered around the old shafts.

References: N. J. 1873, pp. 67–68 and 94; 1879, p. 79.

The Lawrence Farm Explorations.

The Lawrence Farm explorations were southwest of the Gaffney mine, in Byram Township, Sussex County. The pits to be seen here are very old, and nothing is known about them except that they are on the line of attraction passing through the Gaffney mine.

References: N. J. 1873, pp. 67–68 and 94; 1879, p. 79.

(73) The Sickles Mine.

The Sickles mine was 2.75 miles south of Sparta, in Sparta Township, Sussex County, one-quarter of a mile east of the road between Sparta and Brooklyn and three-quarters of a mile northeast of the Gaffney mine.

So far as is known, the mine was first worked in 1870 and 1871 through a shaft 30 feet deep. The ore deposit is said to have been 12 feet wide at the top, but only 5 feet wide at the bottom of the shaft. In a second shaft 150 yards to the northeast its width diminished to 3 feet, but the wall rocks contained ore in thin layers and sheets, the whole being too lean to work. The mine was again operated between 1874 and 1878. It was reopened near the end of the year 1879 and worked through the

succeeding year from a new shaft 500 feet southwest of the old mine. At the bottom of this shaft, which was 60 feet deep, the deposit was 3 to 4 feet wide. In 1882 the northeast shaft was pumped out and explored, but no ore was mined.

The dip of the deposit varied between east and east-northeast. The magnetite is much mixed with feldspar, in some places forming a coarse rock, very closely related to pegmatite.

An analysis of a sample of the ore taken from a pile of 50 tons yielded:

$Fe = 38.11$; $S = .976$; $P = .05$. Authority: 10th Census, p. 158.

The total yield of the mine is said to have been 4,000 tons, of which 2,000 tons were of Bessemer grade.

Northeast of the vein as developed at the Sickles mine is a strong line of attraction, on which a little ore was uncovered by a trench.

References: N. J. 1873, p. 67; 1879, p. 79; 1880, p. 115; 10th Census, p. 158; 1883, p. 136; Folio U. S. G. S. No. 161, p. 22; Geol. Atlas of N. J. No. 2, p. 22.

(75) The Bunker and (74) Sherman Farms Explorations.

The explorations on the Bunker and Sherman farms were about 1 mile southeast of Sparta, on Slack Brook.

The Sherman farm was first explored in the early part of the last century. Before 1854 several openings had been made on a number of irregular deposits measuring from 3 to 10 feet in width, constituting a mineralized zone extending parallel to the foliation of the gneisses in the vicinity. The strike of the veins is the usual northeast direction, but their dip is 35° to 50° northwest, which is contrary to the general rule. The mine was evidently not worked to any great extent in its early years, as it had lost its identity before 1868, and was at that time referred to merely as one of the explorations in the mountains southeast of Sparta.

Between 1873 and 1875 about 100 tons of ore were taken from a large open pit 50 feet long and 35 feet deep. No distinct vein was struck, but there appeared to be present a large body of lean material, which passed gradually into the surrounding gneiss.

The explorations on the Bunker farm were about 50 yards south of those on the Sherman farm. An open cut was made in 1874, or about that time. This developed a deposit which consisted of 5 feet of ore, 5 feet of rock and from 5 to 7 feet of ore, the latter lying on the foot-wall, which dipped 30° south.

The quantity of ore in the neighborhood of the two mines is thought to be large, but the rocks are so badly jointed that the ore bodies are very irregular in shape. Spencer reports that prospecting was in progress during 1904 and 1905 for the purpose of determining the average value of the ore and its quantity, with a view to the possibility of concentrating the lean material.

References: N. J. 1854, p. 37; 1855, p. 164; 1879, p. 79-80; Folio U. S. G. S. No. 161, p. 22; Geologic Atlas of N. J. No. 2, p. 22.

The Dekay Farm Explorations.

The DeKay farm explorations were in Vernon Township, Sussex County, possibly on the extension of the Gaffney belt, somewhere to the east of DeKay's, on the Lehigh and Hudson River Railroad, near the State line.

A well-marked line of attraction runs through the property in the line of strike of the gneiss, and here and there along the line is an outcrop of ore. A small test pit disclosed a vein of workable size, but the ore raised was found to be very rich in titanium, and, consequently, the place was never worked.

An analysis of an average specimen gave:

$$Fe = 45.75;\ SiO_2 = 31.40;\ P = .11;\ S = .41;\ Ti = 2.81.$$

Reference: N. J. 1899, p. 162.

MINES OF THE OGDEN MINE BELT.

The line of mines next east of the Oxford belt begins at the southwest end of Pohatcong Mountain and runs approximately through the central line of this mountain, over Allamuchy Mountain, and over the west side of Wawayanda Mountain, crossing the State line about 1 mile southeast of New Milford, in New York.

At or near it were situated a large number of explorations and unimportant mines, besides the Williams mine and the Ogden group of mines, which were once large producers. The ore as a whole was rather lean.

(76) The Cline Mine.

The Cline mine was near the base of Pohatcong Mountain, 1.5 miles southeast of Stewartsville, in Greenwich Township, near the line between Greenwich and Franklin Townships, Warren County. Another mine of the same name was near New Village (see page 67). This latter produced limonite.

The opening was made some time before 1873, as in this year there was a shaft 20 feet deep on the property and an adit on the vein 200 feet long.

The ore on the dump was lean. It is reported, however, that a considerable quantity had been removed and sold.

There is nothing further known about the mine, nor has its shaft been identified.

References: N. J. 1879, p. 73.

(77) Smith's Openings.

Smith's openings were on the side of Pohatcong Mountain, in Franklin township, Warren County, a few rods east of the Cline mine.

Two shafts 20 feet deep were sunk, and from 200 to 300 tons of ore were mined and shipped before 1873, at which time the place was abandoned.

The ore was lean and contained pyrite.

References: N. J. 1879, p. 73.

The Dean Lot Exploration.

The Dean lot adjoined Smith's openings on the east, in Franklin township, Warren County.

There were two lines of openings 25 feet deep on two veins of very lean ore about 100 yards apart, the western one of which is

about 150 yards east of the Smith openings. On this there were two shafts. There were also two shafts on the eastern vein. About 50 yards distant from the easternmost of these two veins a third one is reported to have been opened by a single shaft.

The place was worked before 1873, but to what extent is not known.

Reference: N. J. 1879, p. 73.

(78) The Creager or Confucius Mine.

The Creager or Confucius mine was on the northwest slope of a little knoll on the south side of the road between Port Murray and Karrville, in Mansfield Township, Warren County, about 1 mile west of Port Murray.

It was opened in 1871 by two shafts, one 50 feet deep and the other 23 feet deep. The ore deposit, which was lean, measured 9 feet in breadth. Very little further work was done, and the place was abandoned in 1873, In 1880 it was explored again, but no mining was attempted.

References: N. J. 1873, p. 61; 1879, p. 75; 1880, p. 113; 1884, p. 101.

A Cregar mine is reported by the 10th Census as having produced 250 tons of ore in 1879–1880. It was located in High Bridge Township, Hunterdon County. No other reference to its existence has been found.

Reference: 10th Census, p. 164.

(79) The Mitchell Mine.

The Mitchell mine was 2 miles north of Port Murray, on the east side of the road between this place and Mt. Bethel, in Mansfield Township, Warren County.

The mine was opened in 1870. From an open cut several hundred tons of good ore were removed. Two shafts were sunk later, but no great quantity of ore was discovered. After spending a large amount of money in exploration the attempt to find good ore in profitable quantity was abandoned.

References: N. J. 1873, p. 61–62; 1879, p. 75.

(80) *Johnson's Explorations.*

Johnson's explorations were about one-half a mile west of the Mitchell mine, in Mansfield Township, Warren County. Their exact situation is unknown, though it is probable that they were on the west slope of the mountain, three-quarters of a mile east of Karrville.

Very little ore was found in a narrow vein. No mining was attempted.

References: N. J. 1873, p. 62; 1879, p. 75.

The Stephenson Mine.

Another exploration, near the Johnson diggings, was locally known as the Stephenson mine. Its exact location has not been discovered. It was probably south of the Bald Pate mine.

References: N. J. 1880, p. 113, and 1890, p. 115.

(81) *The Bald Pate Mine.*

The Bald Pate mine was in Mansfield Township, Warren County, about 2.5 miles north of Port Muray, on the east side of the road to Mt. Bethel, and about 1 mile south of this village.

It is reported that quite a lot of ore was obtained here before 1868, but little is known of its character or the manner of its occurrence. The mine has been operated for short periods at different times, but without great success. It was worked between 1873 and 1876, producing about 2,000 tons of ore. In the latter year it was shut down, but it was again reopened in 1879 and a few months' work was done, 150 tons of ore being raised, when it was again closed.

Three shafts were sunk. In the southeastern one a quartz rock was struck at a depth of 40 feet, which continued to the bottom of the shaft (96 feet deep), and also in a drift northward. The middle shaft was in gneiss and ore, and the northwestern one, which was 60 feet deep, opened a greenish slaty rock on the hanging wall of the vein.

The ore seems to have been in irregular strings in the rock, rather than in the form of a regular vein.

A sample taken from a pile of 75 tons at the mine when analyzed by the chemists of the 10th Census gave:

$Fe = 54.10$; $S = .025$; $P = .039$. Authority: 10th Census, p. 159.

References: N. J. 1868, p. 624; 1873, p. 62; 1879, p. 75; 1880, p. 113; 10th Census, p. 159.

(82) The Shafer or Welch Mine.

The Shafer or Welch mine was near the Bald Pate Mine in Mansfield Township, Warren County, probably about one-half a mile north of this mine, on the west side of the road leading to Mt. Bethel.

A sample of the ore analyzed in 1879 yielded (N. J. 1879, p. 75):

Ins.	Fe_2O_3	MnO	P_2O_5	TiO_2	S	Fe	P
26.40	64.60	tr	.20	4.95	.028	45.22	.09

It is not known that the place was ever worked.

References: N. J. 1879, p. 75.

(83) The Egbert Church Mine.

The Egbert Church, Egbert or Smith mine was one-half a mile north of Mt. Bethel, in Mansfield Township, Warren County.

It was first opened in 1871 by two slopes 150 feet apart, and worked until 1876, during which time it yielded several thousand tons of ore.

At the bottom of the slopes the ore body measured from 6 to 8 feet in width. A short distance above this there was a pinch, and here the ore was only a few inches thick. The strike of the vein was north 15° east, and its dip east-southeast. When abandoned in 1876 the shafts were 130 feet deep, and the ore had been drifted upon for a distance of 220 feet. The composition of a sample taken from a pile of 100 tons gave:

$Fe = 47.37$; $S = 4.010$; $P = .418$. Authority: 10th Census, p. 159.

The line of attraction that passed through the mine was recognizable for a long distance to the northeast, and also to the southwest. Openings made on the northeast extension of the line discovered no ore. Five openings to the southwest, varying in depth from 20 to 40 feet, found ore, but not in large quantity.

One of the explorations northeast of the Church mine must have been of considerable magnitude, for we find on the State map a couple of shafts indicated as (84) Tunnison's mine. No reference to them can be found, however, although the pits can still be seen with their fairly large dump-heaps.

References: N. J. 1873, p. 62; 1879, p. 76; 10th Census, p. 158-159.

(85) The Day Mine.

The Day mine was 1 mile northwest of Hackettstown, on the southwest side of the road to Petersburg, in Independence Township, Warren County.

The mine was little more than an exploration. A shaft 15 feet deep was sunk on the vein in 1880, and a drift was driven 15 feet northeast. Twenty tons of ore had been obtained when work ceased. The ore consisted of magnetite grains imbedded in a mass of white feldspar, probably constituting a pegmatite dike.

An analysis of a sample representing the average of a pile of 20 tons of the ore at the pit gave:

Fe_3O_4=70.26; MnO=.45; TiO_2=5.00; P_2O_5=.10 SO_3=tr; Fe=50.88.
Reference: N. J. 1880, pp. 126-127.

(86) Wintermuth's Mine.

Wintermuth's mine was in Allamuchy Township, Warren County, about 1 mile southwest of Haggerty's mine, and 1.5 miles southeast of Warrenville.

All that is known about this place is the fact that it was opened in 1880, and that the ore was similar to that at the Haggerty mine.

References: N. J. 1880, pp. 124 and 127.

(87) *The Excelsior Mine.*

The Excelsior mine was 3 miles north of Hackettstown, near the canal, in Allamuchy Township, Warren County.

It was first opened in 1871, and thoroughly explored in the succeeding two years. The ore was a magnetite-bearing pegmatite, which in places contained 40 per cent. of iron. As the dike was followed, its course became more and more nearly parallel to the banding of the surrounding gneiss and apparently was changing into an ore vein when the work was stopped.

Reference: N. J. 1873, p. 64.

(88) *The Eureka Mine.*

The Eureka mine was on the south slope of Allamuchy Mountain, overlooking the Morris Canal, and about three-fourths of a mile north of the Excelsior mine, in Allamuchy Township, Warren County.

It was first opened in 1871, uncovering a lean ore that was probably a magnetitic pegmatite. The country between this mine and the Excelsior mine is apparently everywhere underlain by streaks of ore-bearing rock.

The exact location of the pit has not been identified.

Reference: N. J. 1873, p. 64.

(89) *The Cascade Mine.*

The Cascade or Smith mine is on the east side of the Sussex Railroad, about 2.5 miles northwest of Stanhope, in Byram Township, Sussex County.

The mine was worked in 1850 or thereabouts for the Andover forge. It was reopened in 1869 and operated continuously until 1877, when it was abandoned. In 1883 a little work was done near the old shafts and on the hillside west of them, but nothing was developed.

The ore vein varied from 3 to 11 feet in width, and was separated into two parts by an irregular horse of rock. Its dip was

35°–45° east and strike nearly north. The ore contained considerable pyrite.

Sixty yards north of the main openings was a thin vein of very rich ore that was, however, worked very sparingly because of its narrowness. It is described as having the character of a true vein.

References: N. J. 1873, p. 66; 1879, p. 77; 1883, p. 135.

(90) The Allis Explorations.

The Allis explorations were north of and adjoining the Cascade mine in Byram Township, Sussex County. A little ore was discovered here before 1873, and some mining done, but the quantity of ore raised is not known. The work was soon discontinued.

Reference: N. J. 1873, p. 66; 1879, p. 77.

For a distance of 11 miles beyond the Cascade mine there are no openings that disclosed ore. In the next 3.5 miles, however, mine openings are numerous, exposing an almost continuous vein throughout this distance, the most important openings in this stretch being those of the Ogden mines.

Explorations Near Sparta.

A few pits are reported to have been sunk south of Morris Pond, in Sparta Township, Sussex County, and in some of them ore is said to have been found, but as to its quality and abundance nothing has been reported.

Reference: N. J. 1873. p. 68.

(91-92) The Ogden Mines.

The Ogden group of mines includes a number of openings, of which the most important were situated in Sparta Township, Sussex County, about 2 miles southeast of Ogdensburg, at the place now known as Edison.

The mineralized zone in which the mines are located has a maximum width of about 1,200 feet and an average width of 600 feet, and a length of 5.5 miles (Plate IV). At its southwest end the zone separates into three distinct magnetic belts, and at its northeast end it wedges out into four narrow belts. The whole zone has been thoroughly explored by pits, shafts and trenches, which are most numerous around the site of the village of Edison, where formerly the largest mines of the district were situated. Most of the openings at other points in the zone were merely explorations in search of the extension of the ore vein that was known to exist at Edison. Among the points at which operations were carried on were Kinney's mine, Amos Sharp's mine, Bird's mine, the De Camp mine, the Davenport mine, the Morris mine, the Pardee mine and the Roberts mine. A long distance to the south of these another important group of pits was sunk, the most southwesterly of which was known as the (91) Riker mine. The oldest of the openings (that of the Old Ogden mine) was made in 1772, near the present site of Edison. Other pits were put down in the latter part of the 18th century and during the early part of the 19th century. Some of these were worked at intervals under various owners until 1899, when all were abandoned in consequence of the failure of the New Jersey and Pennsylvania concentrating works to concentrate successfully the ores on a commercial basis.

On the map that accompanied the report of 1868, besides the Ogden mine, there is represented a mine to the north under the name Amos Sharp mine, and another to the southwest under the name of the Morris mine. These, however, are not referred to in the text, and we are left in ignorance as to whether they were a part of the group described as the Ogden mines or were independent mines. In the text we find that in 1868 three companies were working in the tract, of which one—the Roberts Iron Company—was operating the Old Ogden mine on a vertical vein 24 feet wide at a depth of 100 feet. The Glendon Company was mining on the same vein northeast of the Roberts Company, finding a thickness of 7–10 feet of ore; and the Stanhope Company was working an old mine near that of the Roberts Company,

and was exploring in a number of pits further southwest. One of the openings situated one-half a mile south of the Ogden mine is incidentally mentioned under the name of the Vulcan Head mine. This was operated before 1854 as the Vulcan mine on two deposits, each of which was about 9 feet wide. One of these contained small quantities of chalcopyrite and malachite.

The principal mines of the group near Edison were worked continuously until 1873, when they produced 27,720 tons of ore. In 1879 the Roberts mine and the Pardee mine, adjoining it on the northeast, were both operated, and in the following year in addition the Davenport mine, which lies southwest of the Roberts mine, and the Old Ogden or Lehigh mine, which lay between the Roberts and the Davenport mines. Shortly after this all the mines were closed except the Pardee, which continued in operation until 1884, and perhaps a few years later.

In 1889 or 1890 practically the entire magnetic belt was purchased by the Edison Company, and a great separator was built with a capacity of 700,000 tons annually. It was proposed to mine the ore and rock together, to concentrate it magnetically and to manufacture briquettes from the concentrates. In 1890 the quarrying of the rock on the west end of the old Ogden workings was begun. This was blasted down and fed into the concentrator with an iron content of 20 per cent. It was concentrated to a 68 per cent. Bessemer ore and made into briquettes. Experimental runs were made at intervals between 1891 and 1897, but none of the product was sold. In 1898, however, a trial run was made, lasting sixty days. About 1,200 tons of ore briquettes and 20,000 tons of sand were produced from a rock containing 10–12 per cent. of iron. Analyses of a shipment of 1,000 tons, made to the Thomas Iron Company, showed a content of 62.83 per cent. Fe. In the following year 75,206 tons of rock were quarried and 10,000 tons of briquettes were shipped. Shortly thereafter all operations ceased, because of inability to manufacture briquettes at a profit.

The richest portion of the Ogden vein was at its northeast end at Edison. To the southwest it became poorer, and all the openings made southwest of the Davenport mine disclosed only

lean ore. Consequently none of these was ever operated. Although most of the ore was of non-Bessemer grade, a small quantity of Bessemer ore was mined. Among the minerals associated with the ore are molybdenite, cyanite, pyrite, chalcopyrite, garnet and crystallized apatite.

The manner of occurrence of the ore is similar to that in many other portions of the Highlands area. It is better exhibited here than elsewhere, however, because of the fine exposures uncovered by the stripping of the surface in anticipation of the operations of the concentrating works. Spencer[1] describes the conditions here as follows:

"The magnetite occurs in both large and small sheets. The larger masses of ore which were worked underground for many years were found to be similar in shape and of comparable size to the ore bodies of many other mines in the crystalline belt, showing the same elongated podlike form, pinching and swelling, southeasterly dips combined with northeasterly pitch, and conformity in attitude to the structure of the inclosing rocks. The three larger mines of the group are said to have worked the same ore shoot, which ranges in thickness from 10 to 30 feet. The ore was mined to a height of 85 to 110 feet, and if actually continuous through the various mines, was worked for a length of nearly 1,500 feet. In addition to this large ore mass, several smaller bodies were discovered, though none of them have developed into important mines. In general the ore in the smaller shoots seems to have contained considerable feldspar and quartz, and some of it carried noteworthy amounts of pyrite.

In addition to the ore shoots that are of such size as to permit independent mining, minor sheets and bunches of magnetite associated with stringers of pegmatite penetrate the gneiss through practically the whole of the ore zone. So considerable is the amount of this distributed orey material that large masses of the rock are reported to contain 20 per cent. of metallic iron."

The Davenport mine was in a lean shoot pitching 35° northeast. The walls were nearly vertical, and the deposit was 6 to 8 feet thick. In 1880 the depth of the mine was 165 feet. The chief gangue of the ore was quartz, which in some cases composed 50 per cent. of the mass of the deposit.

Γhe composition of an average sample taken from a pile of o tons was:

$Fe = 47.76$; $P = .398$; $S = .208$. Authority: 10th Census, p. 155.

—

C. Spencer, Folio No. 161, U. S. G. S. 1908, p. 21. Geologic Atlas of N. J. Folio 2, p. 21.

During about seven months of the census year the mine produced 1,120 tons of ore.

The Roberts mine was operated from two shafts 130 feet apart, from the northeast of which (in 1880) all the ore was raised. This was 270 feet deep. At the depth of 75 feet the ore pinched to 18 inches, but below this it again widened, until near the bottom of the mine the deposit was 15 feet broad. The shoots dipped 65° southeast and pitched 25° northeast.

In 1880 analyses were made of samples taken from the northeast and the southwest stopes, resulting as follows:

N. E. Stopes. $Fe = 63.91$; $P = .613$; $S = .133$; Authority: 10th Census, p. 155.

S. W. Stopes. $Fe = 64.22$; $P = .746$; $S = .105$; Authority: 10th Census, p. 155.

In the census year the production of this mine was 16,800 tons.

The Pardee or Pardee-Ogden mine was on the same shoot as the Roberts mine, but a little further northeast, the "cap-rock" separating the two shafts at the surface. The Roberts shaft started in ore, while the Pardee shaft was sunk through the cap-rock. In 1884 the shaft of the Pardee mine was 375 feet deep. In the stopes 60 feet northeast of the shaft the ore body was 20 feet wide. The shoots were 85 to 110 feet high, and in this mine had nearly vertical walls. At the cap the ore body diminished to a narrow seam; at the bottom it appeared to run out entirely.

About 200 feet north of the shaft a fault exists with a throw of about 17 feet to the right. Its strike is perpendicular to the vein, and its dip is steep south-southwest. A thin leader of ore in the fault plane connected the two ends of the displaced ore-body.

A sample taken from a pile of ore aggregating 2,500 tons possessed the following composition:

$Fe = 59.23$; $P = 1.067$; $S = .113$. Authority: 10th Census, p. 155.

A complete analysis is quoted on page 112. During the census year the mine produced 8,089 tons of ore. Its normal capacity was 20,000 tons.

References: N. J. 1840, p. 27; 1854, p. 26; 1855, p. 164; 1868, pp. 631–632; 1873, p. 68; 1879, p. 80; 1880, p. 115; 10th Census, pp. 154–155; 1883, p. 137; 1884, p. 104; 1890, p. 69; 1891, p. 241; 1896, p. 326; 1897, p. 321; 1898, p. 235;

1899, p. 170; 1900, p. 206. Folio No. 161, U. S. G. S., p. 21; Geologic Atlas of N. J. Folio 2, p. 21.

A weak line of attraction is reported to extend from a point a short distance northeast of the Ogden mines all the way to the New York, Susquehanna & Western Railroad, a distance of 4 miles. A number of pits sunk upon it at different places uncovered lean ore, but not in sufficient quantity to warrant mining. The most promising of these is on the edge of a swamp on the south side of the road between Two Bridges (Beaver Lake) and Stockholm, and about 2 miles northwest of the latter place. It is in Hardyston Township, Sussex County, and is known as the Ward mine. It was never more than an exploration in a small area of slight attraction.

About 7.5 miles northeast of the Ogden mines are the openings of the Williams mine, which, in its day, was an important contributor to the State's output of ore.

Reference: N. J. 1873, p. 68.

(93) The Williams Mine.

The Williams mine is half a mile east of the Vernon-Stockholm road, and 3 miles south of Vernon, in Vernon Township, Sussex County.

The mine must have been opened originally in 1815, or about that time, and worked extensively until about 1830, when it was apparently abandoned. It was later re-opened and operated at intervals until 1870. From this time until 1876 it was worked uninterruptedly and then was closed. It was again re-opened in 1880 and operated for a short period. Work was again resumed in 1881 and continued until 1883, when the mine was closed permanently.

In 1870 three shafts were sunk in a line 400 yards long. At the southwest one the dip of the deposit was northwest. In the second shaft, 1,000 feet northeast of this, the dip was steep to the southeast, as it was also in the third shaft, which was 200 feet further northeast.

The vein was irregular in width, and in the earlier working the ore is reported to have been free from sulphur. That produced

later, however, contained so much pyrite that it had to be roasted before using, although in the bottom stopes, worked in 1883, there was apparently some ore free from sulphur.

When the mine was closed in 1883 the ore had been followed for a distance of 275 feet, with an average width of 11 feet from the main shaft, which was 200 feet deep.

References: N. J. 1855, p. 164; 1873, p. 70; 1879, p. 80; 10th Census, p. 154; 1880, p. 115; 1883, p. 138.

(94) The Segur and Wright Explorations.

Northeast of the Williams mine, on the immediately adjoining property (the Rutherford Estate), some test pitting was done in 1873 which disclosed ore. No mining was attempted, however.

This exploration is also known as the Rutherford Tract exploration.

References: N. J. 1873, pp. 70-71; 1879, p. 80.

(95) The Hunt Tract Explorations.

The explorations on the Hunt farm were northeast of the Segur and Wright explorations in Vernon Township, Sussex County.

Ore was found on two lines of attraction, of which the northwestern one may correspond to a line across the Williams property, about 1,000 feet west of that on which the Williams mine was opened. The eastern line was probably a little east of the Williams line.

No mining was done on either vein.

References: N. J. 1873, p. 71; 1879, p. 80.

(96) The Parker Mine.

The Parker mine was an exploration on Wawayanda Mountain, about 1 mile south of east of Vernon, in Vernon Township, Sussex County, near the crest of the mountain.

Searches were made for ore by two pits sunk in a pegmatite during 1873. The ore found was very lean. None was mined. This opening was a short distance west of the extension northeast of the vein at the Williams mine.

Reference: N. J. 1873, p. 71.

MINES IN THE ROCKPORT BELT.

There appears to be a distinct and well-defined belt of mine holes extending along the east slope of Upper Pohatcong Mountain, about one-half mile east of the Ogden belt. It is marked by eight or nine pits scattered at short intervals from a point west of Port Murray to Buck's Hill, north of Hackettstown. The holes have yielded only small quantities of lean ore, much of which was in the nature of a magnetitic pegmatite. A pit on the top of the hill 1 mile north of Port Murray is notable for the presence of molybdenite coating joint cracks in a very massive basic rock which forms the principal material of its dump.

None of the pits on this line except the Searle mine and the pit on Buck's Hill have been referred to in the Reports of the Survey, so that we know very little of their history.

Explorations Near Rockport.

A number of shafts were sunk near Rockport, in Mansfield Township, Warren County, in about 1870, in search of ore, but without success. Magnetite was observed in the vicinity in coarse pegmatite, but no definite deposits were discovered.

References: N. J. 1873, p. 62; 1879, p. 75.

(97) The Searle Mine.

The Searle mine was on the southeast side of Pohatcong Mountain, in Independence Township, Warren County, about 2 miles southwest of Hackettstown.

A shaft 60 feet deep was sunk prior to 1868, disclosing two very narrow bands of ore separated by rock. A second shaft a

little farther west was sunk 32 feet. From both shafts good shot ore was taken, but the quantity is not known. The mine has not been worked since this time.

Analyses of ore (1) from the surface and (2) from a depth of 50 feet were made with the following results:

Fe_2O_3	SiO_2 and ins.	S	P_2O_5	Met. Iron	Authority
1.—92.6	4.2	tr.	.6	67.0	N. J. 1868, p. 624
2.—76.8	18.2	.0	.2	55.6	N. J. 1868, p. 624

References: N. J. 1868, p. 624; 1873, p. 62.

(98) Buck's Hill Exploration.

The Buck's Hill exploration was on the crest of Buck's Hill, the high point northwest of Hackettstown, in Independence Township, Warren County.

A shaft 30 feet deep was sunk in 1873 on a pegmatite dike, but no ore was found. Other pits situated a short distance west of this one opened into hornblende and biotitic gneisses.

References: N. J. 1873, p. 63.

MINE BELTS ON MUSCONETCONG AND SCHOOLEY MOUNTAINS.

The mines and explorations on Musconetcong and Schooley mountains may be considered as being arranged along four parallel belts about three-fourths of a mile apart, trending parallel to the general direction of the mountain range. On Mount Olive two additional belts originate, one on each side of the other four. At Hopatcong Lake the two eastern belts and the western of the two central ones terminate. Beyond the lake, therefore, only three belts continue, but these extend all the way to the State line.

Although a great number of openings have been made in these belts only a few ever developed into important mines. These were the Ford, Schofield and Dodge mines on the western continuous belt and the Weldon and Hurd mines on the eastern one. The Stanhope mine on the westernmost of the belts has been operating for a long period, but its output is small. At the present time it is the only active mine in any of the belts.

For the purpose of describing the mines systematically the belts are taken up in order, beginning with the westernmost, and the openings situated upon or near each are briefly discussed. It is not intended by this manner of treatment to suggest that all the openings in a belt are necessarily in the same vein. It is certain that this is not so. It is probable that no single vein is as long as any one of the belts, but that the belts are groups of short veins lying parallel to one another and constituting zones of deposits.

Beginning at the west the first belt will be called the Stanhope belt, the second the Ford mine belt, the third the Marsh mine belt, the fourth the Hurd mine belt, the fifth the Van Syckle mine belt and the sixth the High Ledge mine belt.

MINES IN THE STANHOPE BELT.

The Stanhope belt of mines starts on Schooleys Mountain, a mile east of Hackettstown, and runs northeast along the west sides of Lake Hopatcong and Canistear reservoir, and crosses the State line 1.5 miles southeast of New Milford, New York.

The only openings of any consequence upon it are the Stanhope and the Layton mines, the former near its southern extremity and the latter at its northern end. The other openings have been merely explorations, although from a few of them ore has been shipped. The Creamer mine is at the southwest end of the line. The Stanhope and Budd mines are near its central part, a group of five or six pits is at the northern end of Lake Hopatcong, and the Layton mine is near the point where it crosses the State line. Between these openings no others have been made except a few shallow pits that revealed nothing worthy of note.

(99) The Appleget Openings.

The Appleget openings were in Mount Olive Township, Morris County, about 1.5 miles east of Hackettstown, on the road to Drakestown.

From a broad open pit dug in 1880 several hundred tons of lean ore were taken and left on the bank. No distinct vein was found, but there was a line of weak attraction running northeast from the pit.

Reference: N. J. 1880, pp. 112 and 125.

(100) The Creamer Mine.

The Creamer, or Cramer, mine was on Schooleys Mountain, about 1.5 miles east of Hackettstown, in Mount Olive Township, Morris County, on the northwest brow of the mountain. The Warne and Shouse tunnel was apparently near this mine.

Very early in the last century ore was obtained here for a forge near Hackettstown. About 1854 the place was again worked. Nothing is known of the developments during these two periods. In 1872 the place was opened once more and operated until 1875. During the last period three shafts were sunk from 30 to 50 feet deep on a regular line of attraction running northeast. At the surface the vein dipped northwest, but at a greater depth it was vertical, and at the bottom of the shaft it dipped southeast.

Specimens of ore sent to the State laboratory in 1877 yielded on analysis:

	Fe	*TiO_2*	*P*	*S*	*Mn*	*Authority*
Rich ore, ...	62.23	9.80	.14	o	tr	N. J. 1877, p. 49
Lean ore, ...	40.25	4.20	.39	?	tr	N. J. 1877, p. 49

References: N. J. 1877, p. 49; 1879, p. 70.

(101) The Warne and Shouse Tunnel.

The Warne and Shouse exploration was 1.25 miles east of Hackettstown on the road to Budds Lake, in Mount Olive Township, Morris County.

The exploration was in the form of a tunnel driven 300 feet into the hill to intercept a long line of attraction observed on the hill north of the road. Two shallow test pits on the line failed to discover ore, and the tunnel met with no better success.

The exact location of the tunnel has not been identified.

Reference: N. J. 1879, p. 70.

(102) The Smith Mine.

The Smith mine is reported to have been 3 miles northeast of Hackettstown, on Schooleys Mountain, in Mount Olive Township, Morris County. The mine is said to have been near the top of the mountain on the slope facing northwest. It was probably about a mile northeast of the Creamer mine.

Three shafts had been sunk about 1850, one of which was 40 feet deep. The ore was impure in places, but good enough in other places to warrant shipment to Sparta, where it was worked in forges.

The mine was in operation two years, between 1850 and 1852, and was then closed down. It was reopened later (before 1868), and was operated two months, after which it was abandoned.

References: N. J. 1868, p. 620; 1873, p. 59; 1879, p. 70.

(103) The Lowrance Mine.

The Lowrance mine was 1.25 miles west-northwest of Stanhope, just north of the Morris Canal, in what is now Mount Olive Township, Morris County.

Several openings were made before 1855 on one of two parallel seams of ore, which are traceable by their attractions for some distance in a northeast and southwest direction.

The ore was pyritiferous. An analysis made in 1868 gave:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Met. Iron	Authority
65.6	25.4	3.9	.0	47.5	N. J. 1868, p. 622

The place seems never to have been worked.

References, N. J. 1855, p. 175; 1868, p. 622; 1879, p. 70.

(104) The Stanhope or Hude Mine.

The Stanhope or Hude mine is on the south side of a ridge about 1 mile northwest of Stanhope, in Byram Township, Sussex County.

The place has been worked for over 100 years, but never very vigorously. The first openings were made about 1790, a short

distance north of the present mine. In 1850 a new opening was started about 350 yards south-southwest of the old mine, but the ore found contained so much pyrite that the place was abandoned after the removal of several hundred tons of material. In 1873 the mine was reopened and operated by open pits for several years, during which time 3,000 tons of ore were raised. It was again reopened in 1879. By this time about 50 pits had been dug, of which none were over 50 feet deep. The mine was worked for a short period, but was soon again closed. About this time a tunnel was started at the foot of the hill on the southeast side, but it was carried only 100 feet when work was stopped. It was later driven 100 feet further into the hill, cutting the vein that was being worked on the hill. Up to July, 1880, the various openings were estimated to have produced 29,000 tons of ore.

The mine was idle in 1883 and in the succeeding years until 1890, when it was again in operation. In the following year two tunnels were driven into the hill near its base, one from its northwest side and the other from its southeast side. The northern one opened a deposit of compact ore dipping 15° southeast. The south tunnel traversed three deposits, dipping 30° southeast. The mining was limited to the removal of the ore from these three shoots. It is not known how long operations were carried on at this period, but a few years later the record reports the mine idle. Work was resumed in 1901, the operations consisting in drifting from the two tunnels above mentioned. Except during a few short intervals the mine has been actively worked since this time, at the rate of about 10,000 tons annually.

The entire hill seems full of short, irregular bodies of magnetite pitching easterly at low angles (Plate V). Some of them are supposed to have been connected by short folds, but this has not been proven.

The ore found in the older openings was composed of magnetite, hornblende and pyrite, the last-named mineral in some places constituting about one-fourth of its bulk. A notable feature of all the ore in the hill is the presence in it of molybdenite (MoS) and molybdite (MoO_3).

Analyses of the ore raised before 1868 gave:

	Fe_2O_3	SiO_2 and ins.	S	Mo	Fe	Authority
No. 1.—	74.3	15.2	.8	1.1	53.8	N. J. 1868, p. 623
No. 2.—	72.0	21.3	1.2	.0	59.4	N. J. 1868, p. 623

No. 1 was covered with a straw-colored molybdic acid, and in addition contained some molybdenite.
No. 2 was a dark-colored ore containing pyrite.

The principal vein worked in 1879 dipped 30° east. It was 12 feet thick. A portion of the ore obtained at this time was rich and pure, and was used for Bessemer metal. Another portion contained a great deal of pyrite and was fairly high in phosphorus. This was marketed separately. Commercial analysis of two samples obtained in 1880 gave:

	Fe	P	S	Authority
From small openings, west side of hill, ..	49.95	.037	.178	10 Census, p. 158
From pile of 500 tons at Stanhope Furnace,	50.23	.057	1.220	10 Census, p. 158

The shoots opened up by the tunnel of 1891 are short and high (20 to 30 feet), and all pitch to the northeast, some at such high angles as to resemble "chimneys of ore." Their thickness varies between 6 feet and 20 feet.

Analysis of the ore mined in 1901 yielded:

Fe	SiO_2	P	S	Mo	Authority
53.77	14.86	.084	1.342	undet.	N. J. 1901, p. 138

It is reported that the shoots are often faulted into a succession of steps, and that the presence of molybdenum compounds is especially noticeable near pegmatite dikes.

Several test pits were put down on both the northwest and southeast slopes of the hill east of the mine in 1879, but they developed no workable quantity of ore.

References: N. J. 1855, pp. 174–175; 1868, pp. 622–3; 1873, p. 67; 1879, p. 78; 1880, p. 114; 10th Census, p. 158; 1883, p. 136; 1890, pp. 56–57; 1891, p. 239; 1901, pp. 137–138; 1902, p. 118; 1903, p. 102; 1904, p. 295; 1905, p. 317.

(105) The Budd or Wright Mine.

The Budd or Wright mine was about a mile northeast of the Hude mine, in Byram Township, Sussex County, at the west end of a small rocky knoll.

Ore was first discovered here in 1875, and a little work was done during this year in the development of the property. Opera-

tions were resumed in 1879, four openings being made. Of these the principal one was a slope 60 feet deep, descending on the foot-wall of the vein. Forty feet northeast of this was a second shaft. The other two openings were pits about 25 feet deep. One of these was 500 feet southwest of the slope, and the other 50 feet northeast of the shaft. The mine was worked during this year and the greater part of the succeeding two years, its total yield being about 6,500 tons. During this period a third shaft was sunk. In 1906 the mine was again reopened and worked in a small way by several new pits.

The vein, which was drifted upon for 80 feet from the foot of the slope, dipped southeast at 30°. Its strike was N. 50° E. The width of the deposit was 9 feet, but a portion of this consisted of rock. The surface ore was red, while that from a greater depth was blue, and contained considerable pyrite. Analyses of the two varieties raised in 1880 gave:

	Fe	*S*	*P*	*Authority*
Red ore, ...	49.88	1.382	.342	10th Census, p. 158
Blue ore, ...	47.62	2.824	.521	10th Census, p. 158

On the strike of the vein between the shafts and for a distance of 200 yards further northeast is a moderately strong belt of attraction.

References: N. J. 1879, pp. 78-79; 1880, p. 114; 10th Census, p. 158.

THE MINE OPENINGS NEAR WOODPORT.

In the vicinity of Woodport, at the north end of Lake Hopatcong, in Jefferson Township, Morris County, are a number of openings made in search of ore at various times. Some of these are very old; others were dug in the decade 1870-1880. None of them ever found ore in paying quantity, although several produced a few tons each.

Most of the pits are situated on the extension of the line passing through the Stanhope mine, others are further east.

In many cases it is impossible to identify the openings with any of the mines named in the reports of the Survey, but in a few cases this was done.

(106) *The Woodport Mine.*

The Woodport mine was alongside the road between Woodport and Sparta, in Sparta Township, Sussex County, about three-fourths of a mile northwest of the village of Woodport.

Work was done here about 1880 or 1881 on a vein that was reported to be 5 feet or 6 feet wide. The ore was sulphurous, and the mine was therefore not worked.

Reference: N. J. 1883, p. 132.

(107) *The Goble Mine.*

The Goble mine was about 1,000 feet east of the Sparta turnpike, in Sparta Township, Sussex County.

Before 1868 the mine had been worked to a depth of 45 feet through a shaft, but in this year it was found to be abandoned. A second opening 400 yards south of the shaft showed no evidence of ever having been operated systematically.

The ore was black and tough. It was mainly a mixture of magnetite and hornblende. An analysis of material selected from the dump yielded:

Fe_3O_4	SiO_2 *and ins.*	*S*	P_2O_5	*Fe*	*Authority*
83.4	10.9	.0	tr.	60.4	N. J. 1868, p. 613

References: N. J. 1868, pp. 612–613; 1873, p. 66.

The Boss mine was near the Goble mine, but its exact location is not known. It may be the opening situated one-half mile north of the Goble mine pit. The mine was never worked to any great extent, having been abandoned before 1868.

References: N. J. 1868, p. 613; 1873, p. 66.

The Shongum mine was also near Woodport. It was an old place in 1873. So far as known it was never operated.

References: N. J. 1873, p. 66; 1879, p. 73.

The Duffee and Frazer mines were also in this neighborhood, but since they are described as being northeast of Woodport, they

are discussed in connection with the Ford-Schofield belt of mines.

(108) The Fredericks Mine.

The Fredericks mine was in a narrow belt of weak attraction in Hardyston Township, Sussex County, about 1.25 miles west of Stockholm and about three-quarters of a mile south of the New York, Susquehanna and Western railroad.

The mine was probably merely an exploration. Nothing is known of its history.

(109) The Straight and (110) Brown Mines.

About 1.5 miles northeast of the Fredericks mine is a belt of fairly strong attraction about 100 feet wide. On this are two pits about 250 yards apart. The southern one, which is about 600 feet east of the road between Stockholm and Hardystonville, is known as the Straight mine, and the northern one as the Brown mine. Neither assumed any importance. They were little more than explorations made to test the area.

(111) The Card Mine.

The Card mine was another small exploration in Hardyston Township, Sussex County, about 1.25 miles northeast of the Brown mine. The attraction in the neighborhood of the pit is strong but it is limited to an area of a few square yards and consequently is probably of little significance.

(112) The Layton Mine.

The Layton mine is a series of openings in Vernon Township, Sussex County, near the State line, about 1.25 miles southeast of New Milford, New York.

It was first opened in 1878 and explored by shafts and pits on a line 550 feet long. No mining was done at this time, but in 1882 the place was again explored and afterward was operated

about a year, the main shaft being 128 feet deep. The ore varied between 5 and 6 feet in width. It was low in phosphorus and sulphur and carried 55 per cent. iron.

From the great amount of new work seen about the numerous pits it is evident that explorations were resumed at a later date. It is not certain, however, that any considerable quantity of ore was mined.

It is probable that the vein here lies about one-fourth of a mile east of the extension of the main line on the Williams property and about on the extension of that passing through the Rutherford tract.

There are, at present discernible, three old and three comparatively new shafts and a number of shallow pits. The ore visible on their dumps is a granular magnetite containing a little pyrite. It is associated with a pegmatite in which magnetite also occurs as a component and in little streaks.

References: N. J. 1883, p. 139.

MINES IN THE FORD MINE BELT.

This belt is much better marked than any other of the Schooleys Mountain zone. It extends from near the southwest end of Musconetcong Mountain all the way to the northern State line, a distance of some 55 miles, and all along its extent it is marked by pits and mine shafts. It passes through a number of mines that were once important producers, such as the West End and Swayze mines, the Fisher mine, the Dodge, Ford and Schofield mines, the Canistear mine, the Green mine and the Wawayanda mine. It was by no means as productive as the line that passes through the Hurd mine, but its productiveness was more evenly distributed than in the latter case. At its southern end the line is traceable through an almost uninterrupted succession of pits. At its northern end, on the other hand, openings are few and far apart, and yet this portion of the line has produced the most ore.

(113) The Petty Mine.

The Petty mine was at the top of the north slope of Musconetcong Mountain, in Alexandria Township, Hunterdon County, about a mile south of Bloomsbury.

The mine was opened in the early part of 1880 and was worked for three months, during which time about 40 tons of ore were raised.

An analysis of a sample of 25 to 30 tons in the dump is reported by the Thomas Iron Company to show:

Fe	*Al_2O_3*	*CaO*	*Mgo*	*MnO*	*NiO_2*	*SiO_2*	*P*	*S*	*TiO_2*	*Authority.*
54.37	.40	2.32	5.31	.18	.63	14.87	.02	.0	.0	N. J. 1899, p. 166

The ore is notable for its content of nickel.

References: N. J. 1880, pp. 110 and 123; 10th Census, p. 162; 1899, p. 166.

(114) The West End or Turkey Hill Mines.

The West End or Turkey Hill mines included a number of openings extending for a mile on the north slope of Musconetcong Mountain, a short distance southwest of West Portal, Bethlehem Township, Hunterdon County.

The deposit was discovered and opened by a shaft 130 feet deep, in 1872, under the name of the Broderick mine, and by a more shallow one under the name of the Harris mine, and was worked uninterruptedly until July, 1884. The mines were again opened in 1885 and a new shaft was sunk to a depth of 290 feet. Operations continued during the succeeding year, but the mine was abandoned soon thereafter.

The early explorations discovered two veins 60 feet apart, striking north 75° east and dipping 60° south-southeast. The bed rock pitched 45° northeast. The western vein was the thicker and this only was worked to any considerable extent. The deposit varied from 6 feet to 40 feet in width. At its widest point there was a horse of rock 8 feet wide. In 1879 the openings on the vein were a slope 75 feet deep, connecting with a shaft (No. 1) 100 feet further northeast, which was 90 feet deep. No. 2 shaft (163 feet deep) was 630 feet further northeast, and No. 3

shaft (175 feet deep) was 380 feet northeast of this. Shaft No. 4 was 340 feet northeast of No. 3, and the two were connected by underground workings. At points 600 feet, 1,800 feet and 3,000 feet northeast of No. 4 shaft, three other shafts were in process of sinking. The principal opening was No. 4, which was vertical for 75 feet and then inclined on the footwall 160 feet. The total length of the vein developed on the property was 4,450 feet. In addition, the Crane Iron Company's exploration northeast of the West End property proved the vein to extend in this direction, but since this place was not worked it is probable that the ore found was lean or in small quantity.

The yield of the mines was about 12,000 tons annually.

Much of the rock now in the dump is mainly a light-colored Byram gneiss containing numerous layers of magnetite bordered by thin seams of hornblende. Other fragments contain wide layers of coarse hornblende, through the centers of many of which are thin seams of ore.

The ore was of Bessemer grade. It was finely granular and contained hornblende, brown mica and thin veins of calcite. Analyses made in 1880 resulted as follows:

					Authority.
From shaft No.	1.	$Fe = 35.31$	$S = .126$	$P = .006$	10th Census, p. 162.
	3.	$= 30.45$	$= .034$	$= .000$	10th Census, p. 162.
	4.	$= 52.48$	$= .013$	$= .004$	10th Census, p. 162.

References: N. J. 1874, p. 27 (Broderick and Harris mines); 1879 (West End and Crane Iron Co.'s mine), pp. 63–64; 1880, p. 109; 10th Census, p. 162; 1883, p. 123; 1884, p. 94; 1885, p. 104; 1886, p. 152.

(115) *The Bethlehem or Swayze Mine.*

The Bethlehem or Swayze mine was in Bethlehem Township, Hunterdon County, about three-fourths of a mile east of West Portal, on the Lehigh Valley Railroad.

The mine is an old one, much work having been done on the deposit prior to 1868. In this year it was idle, but shortly thereafter it was put into commission and was worked until 1875. It was reopened in 1879 and operated until 1889, when it was abandoned, the yield during these latter years being at the rate

of about 16,000 tons annually. In 1871 the old shafts that had been put down before 1868 had become useless and new ones were sunk further east.

Two veins occurred on the property and ore was taken from both. This was reported to be of Bessemer grade. During the year 1884 the workings encountered a fault which displaced the vein 40 feet to the left.

A continuous line of attraction was traced between the Swayze and the West End mines.

Ore is reported to have been found about one-half mile south of the Swayze mine in considerable quantity. About 500 tons is reported to have been shipped about 1870.

References: N. J. 1868, p. 616; 1873, p. 55; 1879, p. 65; 1880, p. 110; 10th Census, p. 162; 1881, p. 36; 1883, p. 123; 1884, p. 94; 1885, p. 104; 1890, p. 108.

(116) The Rodenbaugh Mine.

The Rodenbaugh, or Rodenburg, mine was on the crest of Musconetcong Mountain, about 300 feet above the Asbury depot, in Bethlehem Township, Hunterdon County.

Three or four openings, about 25 feet deep, were made between 1876 and 1879, finding some lean ore. In the succeeding year the mine was worked one month, and a few tons of ore were produced.

In the most westerly shaft the dip of the vein was northwest. In all others it was southeast. A very little ore was shipped.

References: N. J. 1879, p. 65; 1880, p. 110; 10th Census, p. 162.

(117) The Asbury Mine.

The Asbury mine is in Bethlehem Township, Hunterdon County, on the top of the northwest slope of Musconetcong Mountain, about 1 mile southeast of Asbury. It was opened and abandoned before 1868, about 1,000 tons of ore being shipped between 1854 and 1868. It was reopened in 1879 and worked for a few weeks and then again closed.

The deposit is probably short, for while there is some attraction at the mine, no magnetic lines could be traced from it in either direction.

A tunnel was driven into the side of the hill and from this the workings extended downward 130 feet on a vein 6 feet wide. To the south, higher on the hill, the vein was reached by open cuts. The ore was lean. The northern openings at the top of the hill slope were known as the Lake mine.

References: N. J. 1868, p. 617; 1873, p. 56; 1879, pp. 65-66; 1880, p. 110; 10th Census, p. 162.

The Castner Farm Explorations.

The Castner Farm explorations are reported as being 3 miles northwest of Woodglen, in Lebanon Township, Hunterdon County, on the brow of Schooleys Mountain. The exact location is not known. The Castner farm on which the explorations are said to have been made is 2.5 miles west of Woodglen and 1 mile south of Changewater. It, however, does not extend to the brow of the mountain.

Some ore was mined about 1875, but nothing else is known of the place.

Reference: N. J. 1879, p. 66.

(118) The Mattison Mine.

The Mattison mine was about 1 mile southeast of Anderson, in Lebanon Township, Hunterdon County. Its exact location is unknown.

A little exploring was done in 1880, during the progress of which a vein 5 feet wide was encountered at a depth of 20 feet.

An analysis of the ore made in 1886 by the Thomas Iron Company gave:

$SiO_2 = 30.15$; $TiO_2 = tr$; $Fe = 35.42$; $P = .006$; $S = 4.03$. Authority: N. J. 1899, p. 165.

Other analyses yielded 37.37 per cent. and 37.39 per cent. of iron.

References: N. J. 1880, pp. 111 and 124; 1899, p. 165.

(119) The Fisher Mine.

The Fisher, or Beatyestown, mine is on the brow of Schooleys Mountain, 1 mile south of Beatyestown, in Washington Township, Morris County. It was discovered about 1864 and worked extensively until 1873.

By the year 1868 there had been removed about 10,000 tons of red ore from an open pit 100 feet long, 25 feet wide and 50 feet deep. The ore was 18 to 25 feet thick in the opening, but a few rods further north a shaft 100 feet deep encountered only 6 feet of ore. The ore body appears to have been short, as no magnetic attraction could be detected for any great distance on either side of the mine opening. The ore was quite pyritiferous. At both ends of the opening shafts were sunk, and both penetrated a rich ore containing considerable pyrite.

From present appearances the deposit was on or near the contact of the gneiss and the Cambrian sandstone, but whether any of it was in the sandstone or not cannot now be discovered. Unfortunately, we have no analyses of the ore that might give us some insight into its character.

References: N. J. 1868, p. 618; 1873, p. 59; 1879, p. 68.

(120) Youngs Mine.

On the topographic map a pit is located on the slope of Schooleys Mountain, on the east side of the road between Hackettstown and Schooleys Mountain post office, and 2.5 miles south of Hackettstown. There is no reference to it in any of the reports of the Survey. Since it is only one-half a mile north of the main shaft of the Marsh mine and on the property owned by W. W. Marsh in 1868, it is probably one of the openings of the Marsh mine described on page 314.

(121) The Poole Mine.

The Poole mine was in Washington Township, Morris County, somewhere in the neighborhood of Drakestown, probably a very

short distance west, on the south side of the road to Hackettstown.

The place was explored in 1880, but nothing further is known about it.

Reference: N. J. 1880, p. 112.

(122) The John Smith Exploration.

The John Smith exploration was made in 1905 or 1906, in the woods on the north side of the lake east of Stanhope, between the lake shore and the wagon road running east from Stanhope to Lake Hopatcong. It is not known how deep the pit dug at that time was, but it was probably not very deep. The ore on the dump is lean and very sulphurous.

(123) The Haggerty Mine.

The Haggerty mine was in Byram Township, Sussex County, about 1.25 miles northeast of Stanhope, near the corner of the roads to Roseville and Lake Hopatcong.

There are openings on both sides of the road running north. Some of them were made prior to 1855, as in that year they were found to be abandoned and full of water. Others were made later, but at what time is unknown.

The ore contained pyrrhotite, pyrite and apatite in considerable abundance. The pyrite was in seams and irregular bunches, mixed with magnetite, hornblende and feldspar.

The ore gave on analysis:

Fe_3O_4	SiO_2 *and ins.*	*S.*	P_2O_5	*Authority.*
49.8	9.4	15.4	1.1	N. J. 1868, p. 263.

References: N. J. 1855, p. 174; 1868, p. 623; 1873, p. 67; 1879, p. 79.

Beyond Haggerty's mine are several openings on the west side of Lake Hopatcong. Only one of these, the Lawson mine, is referred to in the reports of the State Survey. Another, the Passaic mine, is located on the topographic map. Concerning the others no information has been found. In all likelihood, none of them produced any considerable quantity of ore.

(124) The Lawson Mine.

The Lawless, or Lawson, exploration was south of the west end of Byram Cove, Lake Hopatcong, in Byram Township, Sussex County.

A vein of ore 3 to 4 feet wide was opened in 1880, and a small quantity of ore was mined. The deposit dipped southeast between well-defined walls. The ore was sulphurous and contained some titanium, but was low in phosphorus.

References: N. J. 1880, pp. 114 and 127; 1883, p. 136.

THE MINES NEAR WOODPORT.

Of the mines near Woodport, two, the Frazer and the Duffee, were probably on this line of openings, although the exact locations of neither of these has been identified. It is possible that the Duffee mine was the opening indicated on the topographic map as being situated on the west side of the Ogden mine branch of the Central Railroad of New Jersey about one-half a mile southwest of Ford station.

(125) The Frazer Mine.

The Fraser, or Frazer, mine is reported as being 1.5 miles northeast of Woodport, in Jefferson Township, Morris County.

It was opened about 1867. Explorations made in the following year disclosed a vein 3.5 feet thick and at least 300 to 400 feet long. It was not operated, so far as can be learned.

References: N. J. 1868, p. 613; 1873, p. 66; 1879, p. 73.

(126) The Duffee Mine.

The Duffee mine was about 2 miles northeast of Woodport, in Jefferson Township, Morris County.

It was opened some time previously to 1855. In 1868 it was found to be abandoned and full of water.

The ore body dipped uniformly at 70° southeast. At the surface it was 3.5 feet in thickness, but at the bottom of the shaft, 30 feet deep, it was only 18 inches thick. The ore seems to have occurred in pegmatite.

References: N. J. 1855, p. 165; 1868, pp. 613–614; 1873, p. 66; 1879, p. 73.

THE DODGE, FORD AND SCHOFIELD MINES.

The Dodge, Ford and Schofield mines are situated very close together in Jefferson Township, Morris County, on the road between Woodport and Milton, about 3 miles west of the latter town. The Dodge mine adjoins the Ford mine on the southwest, and the Schofield mine joins it on the north. The shafts of the Ford and Schofield are very close together, while that of the Dodge mine is about one-half mile further southwest.

Two approximately parallel ore bodies were worked at each of the mines. The Dodge mine is on the strike of the veins at the other mines, and is connected with them by a definite line of magnetic attraction. The three mines are, therefore, probably on the same veins, although up to the present time no physical connection between the Dodge and the other mines has been proven.

In the case of all the mines the prevalent country rock is the ordinary Byram gneiss, and this is intruded by pegmatite in great quantity. Some of the pegmatite contains magnetite. The iron-content of the different ore-bodies mined varied about 9 per cent., but the ore of each mine was fairly constant.

"The ore bodies conform to the foliation of the inclosing gneiss. From the development of the mines it is apparent that the shoots are thickened portions of practically continuous layers of orey rock. Two shoots worked in the Ford mine were separated by a 22-foot horse of rock in the upper workings of the southwestern part of the mine. Both ore bodies pitched toward the northeast, and with increasing depth in this direction they were found to approach, until at a depth of 250 feet in the northeastern shaft of the Ford mine they came almost together. Farther to the northeast, with greater depth, they were again separated by a plate of rock, and were stoped separately to the bottom of the mine. The drawings of the mine workings (Fig. 15) show clearly that the line along which these two veins lie near each other has approximately the same average pitch to the east as the ore shoots themselves, and that above and below this line they are farther apart. The shoots

were not capped or bottomed by entirely barren rock, but the thickness of the ore decreased in the roof and floor, and the veins were not followed where they were thinner than 2 feet. Both the top and bottom edges of the shoots as thus limited were found to descend toward the east, the height of workable ore remaining nearly constant, though showing local variations. The average pitch of the shoots amounts to about 38°. The dip of the foliation in the gneiss parallel to the dip of the ore veins ranges from vertical to about 80°, the steeper inclination being in the lower levels.

"The northwest or foot-wall ore layer, known as the Glendon vein, averaged between 9 and 12 feet of workable ore, and the hanging-wall layer, or Ford vein, was somewhat wider."[1]

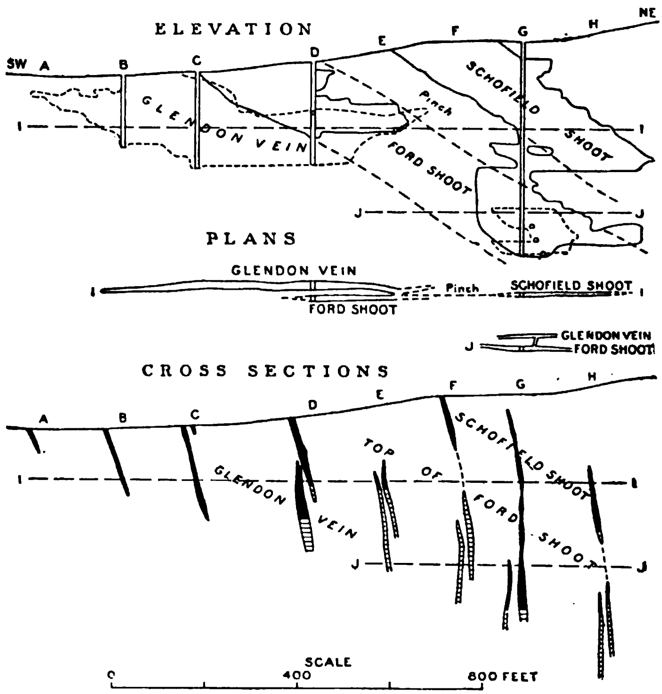


Fig. 15.

Elevation, plans and sections of ore-bodies and workings of the Ford and Schofield mines. In the sections stoped ore is shown in solid black; inferred veins are cross lined.

[1] A. C. Spencer, Folio 161, U. S. Geol. Survey, p. 22; Geologic Atlas of N. J., Folio 2, p. 22.

(127) *The Dodge Mine.*

This mine has had a long history. It was opened before 1868 by two shafts, one 90 feet and the other 120 feet deep, and the single vein then known had been worked for a distance of 100 feet. Although there is no record to this effect, it is probable that operations continued until 1873, and that the mine was then shut down. It was reopened in 1880 and operated during that year and the succeeding one, when it was again closed. It was opened again and worked for a short time in the latter part of 1883 and the earlier portion of 1884, when it was again closed because of the lack of a demand for ore. It has not been worked since.

The vein was 12 feet thick, and was traceable to the northeast quite to the property of the Ford mine by a line of magnetic attraction. The pitch of the ore shoot was 30° northeast, and its dip was northwest. In 1880 the hoisting shaft was down 165 feet, and was bottomed in the bed rock of the shoot. At a point 230 feet northeast of the foot of the shaft the cap rock suddenly descended and apparently cut out the ore. Explorations into the southeast wall disclosed a second ore shoot, separated from the first one by 10 or 12 feet of rock. This where broken into was found to be 20 feet thick, but it narrowed to 8 feet toward the southwest. This shoot furnished practically all the ore that was raised in that year. The veins are reported to dip very high to the northwest, but the ore shoots, as usual, pitched northeast. It is probable that the two shoots in this mine are thickened portions of the same two veins that were mined further northeast in the Ford and the Schofield mines.

A sample of the shipping product mined about 1873 analyzed as follows:

$Fe = 50.70$; $P = .168$; $S = .443$. Authority: 10th Census, p. 156.

About one-eighth of a mile west of the main shaft an exploring shaft was sunk in 1880, near the Ogden branch of the Central R. R., on a line of magnetic attraction. At a depth of 60 feet it struck a 3-foot wide deposit of ore, but this was apparently not worked.

References: N. J. 1868, p. 614; 1873, p. 65; 1879, p. 72; 1880, p. 112; 10th Census, p. 156; 1883, p. 131; 1884, p. 99; Folio No. 161, U. S. Geol. Survey, page 22; Geologic Atlas of N. J. Folio No. 2, p. 22.

(128) The Ford and (126) Schofield Mines.

The Ford and the Schofield, or Scofield, mines are treated together, partly because they were worked together during the latter part of their history and partly because their deposits must be described together in order that a proper realization of their relationships may be obtained.

As early as 1855 the deposit worked through the Ford opening had been mined to a depth of 104 feet, and that worked through the Schofield shaft had been mined to a depth of 40 feet. The two shafts were 130 feet apart, and both were evidently operated in this year.

The Scofield mine was worked almost constantly until 1874, when mining was temporarily suspended. Operations were resumed in 1880 and continued until 1890, at which time the mine was closed because of the low price of ore. It is reported that considerable ore was left in the mine when abandoned.

The Ford mine was also worked continuously until about 1874, when it was closed, to be opened again in 1879. From this time to 1883 it produced about 20,000 tons of ore annually. The mine was closed during the latter part of this year, but it was reopened in 1884. It was again closed in 1885, but was again reopened in 1886, producing in this year about 15,000 tons. It was finally abandoned in 1896. By this time the east deposit, referred to below, had been entirely worked out, although in the west vein there still remained a little ore. In 1899 a small quantity of ore was obtained from above water level, but the mine was not operated systematically.

In the Ford mine were two veins, the western or foot-wall vein being known as the "Glendon" and the eastern or hanging-wall vein as the "Ford." They were separated by 22 feet of rock at the depth at which work was being carried on in 1883. The walls of both veins dipped steeply (85°) to the southeast and pitched 38° northeast. At the northeast part of the mine the

two ore bodies approached one another, and at the depth reached in 1886 (250 feet) this double shoot apparently became a single one and pitched under the shoot mined in the Scofield mine. (See Fig. 15.) Beyond this point to the northeast they again separated and remained apart to the bottom of the mine.

Both shoots in the Ford mine were very large, the Glendon shoot measuring from 9 feet to 12 feet in width and 400 feet in length. The Ford shoot furnished nearly all the ore mined in 1879 and later. This ore was finely granular and contained hornblende, pyrite and apatite. A sample obtained from a pile of 6,000 tons at the mine gave:

$Fe = 50.70$; $P = .313$; $S = .753$. Authority: 10th Census, p. 156.

A shipment made in 1899 yielded:

$Fe = 53.89$; $P = .319$; $S = .498$. Authority: N. J. 1899, p. 169.

From the brief descriptions of the Dodge, Ford and Schofield mines given above it is evident that these mines are not exhausted, and that under favorable conditions they may again be made to yield a great quantity of ore. Spencer[1] remarks that:

"The strongly defined character of the ore shoots and the apparent persistence of the ore layers in which they occur make it seem very probable that they can be followed profitably to a much greater depth than was reached in the now abandoned mines. Just how far they may be expected to continue cannot, of course, be determined out of hand, but it would seem that the facts warrant further exploration on an extended scale.

"If the two parallel shoots in the lower part of the Schofield mine correspond with the two shoots of the Ford mine, as there is every reason to believe that they do, one of them is developed for 1,000 feet and the other for 1,200 feet along the pitch. For more than two-thirds of these distances they were mined to a width (measured in the plane of dip at right angles to the pitch) of 100 to nearly 200 feet, and found to be perhaps 6 or 8 feet thick on the average. There is ore on both shoots in the bottom of the Schofield mine, and so far as known nothing was found to suggest that either the width or the thickness of minable ore is decreasing. On the contrary, the top of the Ford shoot on the hanging-wall vein shows a distinct flattening in the northeast stope, and this stope has been carried nearly to the probable position of the lower edge of the upper shoot, if this edge continues with its average pitch beneath the floor of the upper stope. It seems, therefore, that this lower shoot should continue for some distance below the present work-

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[1] A. C. Spencer. Folio No. 161 U. S. G. S. 1908, p. 22. Geological Atlas of N. J. Folio No. 2, p. 22.

ings. The Schofield shoot has been mined out for a length of 400 feet without narrowing, and it too, with very little doubt, will hold its own for several hundred feet at least. If it actually continues, it may still contain as much ore above the bottom of the Schofield mine as has been removed from it.

"A much longer step into the realm of inference is the suggestion that the Dodge shoots may extend far enough on the pitch to reach beneath the Ford and Schofield workings. The only basis warranting such a suggestion is a comparison with more fully developed localities in the State, where the pinch and swell feature of the veins and the pitch of the ore shoots are always found. The facts determined at the Hurd mine, two miles south of Ford, are distinctly favorable to the idea of the persistence of individual shoots. In this mine a shoot was followed and worked out for a length of about 6,000 feet on the pitch, and in this distance only minor variations in width were found. Among other striking examples the body of zinc ore at Franklin Furnace may be mentioned as having been developed for a length of more than 3,000 feet, and the mines of the Hibernia group, in Morris county, have revealed a continuous vein of ore which extends for 1½ miles and whose limits are still undetermined. * * *

"If the Dodge shoots extend beneath the Ford workings, they lie at a considerable depth, say about 800 or 900 feet, below the bottom of the Ford and Glendon shoots, if we assume the same average pitch as has been determined for these shoots, which is approximately the same as that recorded for the shoots in the Dodge mine. Between the Dodge shaft and the southwestern shaft of the Ford the position of the shoots would lie proportionately nearer the surface, and it is evident that prospecting for the northeasterly continuation of the Dodge shoot would first be undertaken in this part of the belt. The troublesome feature which would attend prospecting with the diamond drill along this ore zone is the nearly vertical average dip of the veins and the fact that the dips vary both ways from a vertical plane."

References: N. J. 1855, p. 164; 1868, pp. 614-616; 1873, p. 66; 1879, p. 72; 1880, p. 113; 10th Census, p. 156; 1883, p. 131; 1884, p. 99; 1885, p. 105; 1886, p. 141; 1890, p. 114; 1896, p. 325; 1899, pp. 159, 169-170; Folio No. 161, U. S. Geol. Survey, p. 22; Geologic Atlas of N. J., Folio 2, p. 22.

In the Schofield mine the deposit worked prior to 1880 was the "old vein," later distinguished as the Schofield shoot. This was a large lens 110 feet high and 4 to 6 feet wide. It dipped 79° southeast and carried ore averaging between 63 per cent. and 65 per cent. of iron. In this year a second shoot was discovered 92 feet below the "bed rock" of the old shoot. This dipped vertically and pitched 35°–40° northeast. Its breadth was 18 feet. Its ore contained 50 to 54 per cent. Fe and .9 per cent. S. Phosphorus was low. Both of these shoots were supposed to be in the extension of the "Glendon vein" worked in the Ford mine, and this view was later confirmed by the discovery of a third ore body in

the hanging-wall of the lower shoot and 10 or 15 feet distant from it. This is in the relative position of the Ford shoot that was worked in the Ford mine. This pitched under the Schofield mine shoot at an angle of 38°. Reference to Fig. 15 will make these relations plain. In later years all the mining was done in this lower shoot, which came over from the Ford property, and the remaining ore in the Schofield shoot was kept as a reserve. The ore of this shoot averaged 52 per cent. Fe, and contained between 0.016 per cent. and 0.75 per cent. S and a very little phosphorus.

References: N. J. 1855, p. 164; 1868, pp. 614-616; 1879, pp. 72-73; 10th Census, p. 156; 1880, p. 113; 1883, p. 131; 1884, p. 99; 1885, p. 105; 1886, p. 151; 1890, p. 114; 1896, p. 325; Folio No. 161, U. S. Geol. Survey, 1908, p. 22; Geologic Atlas of N. J., Folio 2, p. 22.

(130) Hopewell Forge Explorations.

A line of attraction has long been known to exist near Hopewell, in Sparta Township, Sussex County. It has been tested at many points, but without yielding favorable results.

A mile south of the village, on the line between Jefferson and Sparta townships, an exploration known as the Wood's mine disclosed a lean ore. It is in an area of strong attraction, but so far as known no merchantable ore was ever obtained from it.

References: N. J. 1873, p. 68; 1879, p. 80.

The Stockholm Mine.

The Stockholm mine exploration was situated about a mile from Stockholm, probably in Hardyston Township, Sussex County. Its exact location is unknown.

In 1880 a vein 11 feet wide was opened on a long line of attraction. The ore analyzed:

$Fe = 67.10$; $S = .61$; $Mn_3O_4 = 3.74$; $TiO_2 = 3.60$; $P = $ tr; $SiO_2 = .32$.

So far as can be determined the place was never worked.

Reference: N. J. 1881, p. 38.

(131) *The Woods Mine.*

The Woods mine is an exploration about one-half a mile east of Stockholm on the north side of the road, between this village and New Foundland, in Hardyston Township, Sussex County. Nothing is known of its history. Since it is situated in a very small area of attraction it was probably never of much promise.

(132) *The Tracy and Crane Farm Explorations.*

The Tracy and Crane Farm explorations were a short distance northeast of Stockholm, in West Milford Township, Passaic County, about three-fourths of a mile from the railroad station.

A rich ore containing very little sulphur was found here about 1870, and a small quantity was shipped. Nothing further was done, however. The pits have not been visited.

References: N. J. 1873, p. 70; 1879, p. 80.

(133) *The Henderson Farm Explorations.*

The Henderson Farm explorations were about a mile north of the Tracy and Crane property, near Stockholm, in Hardyston Township, Sussex County, on the east side of the road, between Stockholm and Canistear.

Ore was uncovered in 1872 by a single opening on a line of strong attraction. The vein was 18 feet wide. Only a small quantity of ore had been raised when the place was abandoned.

References: N. J. 1873, p. 70; 1879, p. 80.

(134) *The Kimble Farm Exploration.*

The Kimble, or Kimball, Farm explorations were 2 miles northeast of Stockholm and 1 mile southeast of the south end of Canistear Reservoir, in West Milford Township, Passaic County.

Three trial shafts were sunk between 1868 and 1873, one striking lean ore. After this experience work ceased.

References: N. J. 1873; pp. 68-69; 1879, p. 81.

(*135*) *The Day Mine.*

The Day mine was immediately south of the Canistear mine, in West Milford Township, Passaic County.

The character of the ore and the associated rocks and their relations are similar to the features at the Canistear mine.

(*136*) *The Crane Pit.*

A few rods north of the Day mine is an exploration known as the Crane pit. The ore is like that at the Canistear mine. It was never worked.

(*137*) *The Canistear Mine.*

The Canistear mine was in Vernon Township, Sussex County, about one-half mile east of the southern end of Canistear Reservoir, and about one-fourth of a mile northeast of the Kimble explorations.

Three veins were explored about 1870, and ore was raised from each. It was rather lean and contained some pyrite, but it found a market. The mine was worked at intervals until 1880, when, the demand for ore slackening, it was closed. In the census year 1879–1880 about 10,000 tons were mined, the composition of which, as represented by a sample of 350 tons taken by the chemists of the 10th Census, was:

$Fe = 35.38$; $P = .084$; $S = .942$; Authority: 10th Census, p. 154.

The rock in the vicinity is composed of evenly banded Losee and Pochuck gneiss, which in many places is very much contorted and is full of pegmatite.

References: N. J. 1873, p. 70; 1879, p. 80; 1880, p. 115; 10th Census, p. 154.

(*138*) *The Sullivan Mine.*

The Sullivan, or Sulvan, mine was a small opening about one-half mile north of the Canistear mine, in Vernon Township, Sussex County. No ore was ever obtained from it. The pit is now filled up.

The Scranton and Rutherford Explorations.

The Scranton and Rutherford tract is reported as being west of the Budd and Hunt tract, in West Milford Township, Passaic County.

Ore was found in a number of test pits sunk about 1870 on a line of very strong attraction, but no mining was undertaken.

A little further northwest two other lines of strong attraction were also tested by a few shallow pits, and a pyritiferous ore was found.

References: N. J. 1873, p. 69; 1879, p. 81.

(*139*) *The Green Mines.*

The Green mines were on Wawayanda Mountain, in Vernon Township, Sussex County, about 2.5 miles northeast of Wawayanda Lake. There are a number of large openings alongside the road, and from these a great quantity of ore was obtained.

In 1853 there were three openings, of which one was about 180 feet west of north of the second, while this was 250 feet northeast of the third. The last two were evidently on the same vein which was east of that worked at the first opening.

In the first hole was found a seam of ore 1 foot wide composed of hornblende and magnetite. Its strike was north 50° east, and dip 72° southeast. The foot-wall of the seam was definite, but at the hanging-wall there was a gradual transition from ore to rock without any line of demarkation between them.

In the opening next south the ore seam was about 2 feet wide. The magnetite was intermingled with hornblende. In 1853 this opening was 8 feet long, 5 feet wide and 18 feet deep and full of water.

The third opening—the one furthest south—was worked to a depth of 7 feet. The ore body was 3.5 to 4 feet thick, and was imbedded in hornblende. The vein dipped southeast at 65°. It consisted of interlaminations of ore, hornblende, and mixtures of the two, with or without feldspar.

Between 1853 and 1868 several other holes were made to the southwest, and in these the appearance of ore bodies of value was

more promising. The mines were not worked, so far as is known, between 1868 and 1880, but in the latter year they were reopened and operated for a short period. They were abandoned in 1888.

References: N. J. 1855, p. 163; 1868, pp. 632–635; 1873, p. 71; 1879, p. 81; 1880, p. 115; 10th Census, p. 154; 1890, p. 120.

(*140*) *The Wawayanda Mine.*

The Wawayanda mine was in Vernon Township, Sussex County, immediately north of the Green mines.

In 1854 there were openings on five irregular deposits of ore of variable thicknesses, dipping from 15° to 50° southeast. The most regular deposit was that encountered in the northwesternmost opening. This was entered by a tunnel, the mouth of which was 85 feet further northwest. The vein was 2 to 8 feet wide, and had been worked to a depth of 60 feet below the tunnel in 1856. A second deposit was 47 feet southeast of this, and was 2 to 12 feet wide. This second deposit had been worked to a distance of 50 feet on both sides of the tunnel, which was 50 feet beneath the surface at this place. A third deposit from 4 to 20 feet wide was 100 feet southeast of the second. It had been worked for a distance of at least 105 feet along its strike. A syenite (pegmatite?) dike is reported to have intersected this deposit at its southeast end, separating it into two parts, of which the northeastern one was apparently a branch of the main or southwestern one. This branch had likewise been worked for 100 feet. The situation of the fifth deposit is uncertain. It was not worked in 1856. In 1867 the property was purchased by the Thomas Iron Company, after all the openings had been abandoned.

Between 1873 and 1877 the mine was again worked, but it was again closed in the latter year. It was worked in 1880 and 1881, and 4,737 tons of ore were shipped. In 1887, 1890 and 1891 small amounts were again shipped, aggregating about 454 tons. It is unknown whether the mines were operated during these years or whether the shipments were from old stock piles.

The shafts and pits of the Green and Wawayanda mines cover an area about 500 feet long and 125 feet wide, indicating a mineralized zone of this breadth.

Fifteen carloads of ore shipped in 1891 were sampled and gave:

$Fe = 54.33$; $SiO_2 = 12.68$; $MnO_2 = 0.34$; Authority: B. F. Fackenthal, Jr.

References: N. J. 1854, pp. 34–36; 1855, p. 163; 1868, pp. 636–7; 1873, p. 71; 1879, p. 81; 1880, p. 115; 10th Census, p. 154.

THE MARSH MINE BELT.

This line of mines extends from Delaware River northeastward over Musconetcong and Schooleys mountains to within 5 miles of Budds Lake. There are no openings north of Budds Lake that are near the projection of the line northeastward except a test pit on the peninsula between the river Styx and the main body of Lake Hopatcong, and the Welling mine, near the State line. These are not directly in the line, but they are so close to it that they may as well be described in this place.

The belt has never been productive. Several of the mines have shipped ore, but the quantity has been so small individually and in the aggregate that the contribution made to the ore production of the State is negligible. Most of the openings are little more than explorations. They have proven the existence of numerous small deposits of magnetite, but the ore found has been so lean that it has never been profitable to mine.

The first opening on this line is an old one on the top of the southwest end of Musconetcong Mountain overlooking Delaware River. On the topographic map this is indicated as being a location for hematite, but an inspection of the dump heap shows that the ore was lean magnetite. (See Nolf Farm mine, page 86.)

(141) *Hart's Exploration.*

Hart's exploration was in Holland Township, Hunterdon County, on the top of Musconetcong Mountain, about one-half mile southeast of Finesville.

Openings were made in 1880 on a belt of attraction 150 feet long. A shaft was sunk to a depth of 52 feet, but no ore was

found, nor was there any attraction noticeable below a depth of 20 feet.

Reference: N. J. 1880, p. 123.

(*142*) *Sinclair's Explorations.*

Sinclair's explorations are described as being 1 mile northeast of Spring Mills, in Holland Township, Hunterdon County.

An attraction was tested in 1880 by a shaft 40 feet deep, but only a thin streak of rich ore was found. Sinclair's farm is situated north of Spring Mills on the county map, hence it is probable that the explorations were north of the village instead of being northeast.

Reference: N. J. 1880, pp. 110 and 123.

(*143*) *The Wright Mine.*

The Wright mine was in Alexandria Township, Hunterdon County, about 1.3 miles southeast of Bloomsbury and 1.5 miles southwest of the West End mines.

A shaft 35 feet deep was sunk in 1880 and 10 or 12 tons of ore were raised, which was reported as being similar to that from the West End mines.

References: N. J. 1880. pp. 110 and 123.

(*144*) *The Henry Mine.*

An opening about 1.75 miles northeast of the Wright mine, in Bethlehem Township, Hunterdon County, is named the Henry mine on the topographic map of the State.

The mine consists of a single opening, on the dump of which is a quantity of lean ore. Nothing is known of its history or the character of its ore.

Beyond the Henry mine there are no openings on this line for a distance of about 15 miles. In the vicinity of Pleasant Grove, however, there are several old mines, of which the westernmost one, the Pidcock mine, is arbitrarily placed on the line, although, of course, no connection can be traced between its deposit and the deposits of the Henry and Wright mines to the southwest.

(145) *The Pidcock Mine.*

The Hunt or Pidcock mine was near the old Washington turnpike, 2 miles east of Pennville, in Lebanon Township, Hunterdon County, on the top edge of the northwest slope of Schooleys Mountain.

The mine was first opened about 1800 to supply local forges, but was not operated to any extent until it was reopened in 1871 by a shaft 70 feet southwest of the old mine hole. After working a short time it was closed down and remained idle until 1880, when 140 tons of ore were mined. The shaft at this time was 65 feet deep.

The vein uncovered by the later explorations was found to be 5 feet to 8 feet wide and to dip 60° southeast. The ore was lean. East of the mine holes is a line of attraction about 100 feet long.

References: N. J. 1873, p. 56; 1879, p. 66; 1880, p. 111.

(146) *The Sharp Mine.*

The Sharp mine was a few hundred rods southwest of Pleasant Grove, in Washington Township, Morris County. Its situation is a little east of the Marsh mine belt of mines, and about midway between it and the next belt east.

The first openings must have been made about 1871. They were reported as failures because of the neglect to explore thoroughly. Explorations must have been resumed in 1873, for we learn that a shaft 60 feet deep was dug in 1874, and about 50 tons of ore were removed from a narrow vein. The place was then abandoned.

References: N. J. 1873, p. 57; 1879, p. 66.

(147) *The Marsh Mine.*

The Marsh mine was in Washington Township, Morris County, about one-half mile north of Schooleys Mountain, on the east side of the road from this place to Hackettstown.

It was opened in 1855. Between this year and 1868 two large pits had been dug and 4,000 tons of ore raised. The place was again worked in 1872-3, and a new shaft sunk, though little mining was done. In 1882 some new explorations were undertaken and another shaft was sunk, 50 feet deep, but the ore found was siliceous and was therefore not worked.

Of the early openings the southwestern one was a pit 125 feet long and 30 feet to 40 feet deep. The ore body uncovered was very irregular. Its main portion dipped north-northeast at angles varying between 25° and 60°. At the northwest side of the opening, however, there was a branch vein from 4 feet to 6 feet wide, striking west-northwest and dipping 40° to 60° north-northeast.

In the northeast opening two detached and irregular ore bodies were worked. The northeast one dipped 40° to 50° northeast, while the southwest one dipped 60° to 70° southwest. No connection was observed between the two deposits in this pit, nor between either of them and those in the southwest pit.

In both pits the ore was imbedded in decomposed gneisses, and in neither case was it thought to be in place.

The ore was black and compact in some places, and in others it was crystalline. An analysis of this ore gave:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Fe	*Authority*
56.1	35.2	.0	.6	40.6	N. J. 1868, p. 619

The shaft sunk in 1872-3 found a vein 3 to 4 feet wide, dipping southeast. This ore was also comparatively rich.

Fe	S	P	Mn	TiO_2	*Authority*
57.62	.055	.167	.0	2.05	N. J. 1879, p. 69

The ore discovered in 1882 was in a deposit 5 feet wide. It contained between 45 per cent. and 50 per cent. metallic iron.

The strong magnetic attraction observable in the vicinity of these openings suggests the presence of considerable ore beneath the surface. It is probable, however, that it occurs in numerous small deposits.

References: N. J. 1855, pp. 179–180; 1868, pp. 618–619; 1873, p. 59; 1879, pp. 68–69; 1883, p. 125.

Dickinson's Mine.

Dickinson's mine lay about one-quarter of a mile east of Marsh's mine. It was a small opening on ore like that at the Marsh mine. The mine was in operation in 1855.

Analyses of the ore made in 1868 gave:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Fe	Authority.
61.9	24.2	.2	tr	44.9	N. J. 1868, p. 620
79.3	14.0	.0	.4	57.4	N. J. 1868, p. 620

References: N. J. 1855, p. 180; 1868, pp. 619–620; 1873, p. 59; 1879, p. 69.

(*148*) *The Budd and Hunt Tract Explorations.*

The Budd and Hunt tract was near the head of Dunker Pond Brook, in West Milford Township, Passaic County.

The place, which is about half way between the Kimble mine and Buckabear Pond, was explored in the early part of the last century and abandoned. The search for ore was resumed in 1872, on a line of strong attraction, and a lean ore containing pyrite was found. It was not further explored.

References: N. J. 1873, p. 69; 1879, p. 81.

(*149*) *The Jennings and Rutherford Tract.*

The Jennings and Rutherford tract is in West Milford Township, Passaic County, near the west line of the township.

A strong line of attraction is said to run in a northeast direction across the county line into Sussex County, and to be traceable all the way to the Wawayanda mines. The southern end of the magnetic line was explored by pits which uncovered a lean pyritiferous ore vein 8 feet wide. Further north, on the Rutherford property, a vein 24 feet wide was uncovered by two trenches in which the ore appeared to be of good quality. No mining, however, was done, unless the Rutherford property referred to is that described on page 166.

References: N. J. 1873, p. 69; 1879, p. 81.

(150) *The Welling Mine.*

The Welling mine or Ten Eyck's exploration was near the State line, about 1 mile east of the Green and Wawayanda mines, in Vernon Township, Sussex County, on the east side of the road between New Milford and Greenwood Lake.

A long line of strong attraction was opened at five points about 1855, and a lean ore was uncovered at each. Some of it was sent to the Wawayanda furnace. Additional exploratory work was done between 1873 and 1876. In 1879 a number of new openings were made in the neighborhood of the old ones and 400 tons of ore were raised. It was, however, not shipped.

The rocks dipped high to the southeast at the openings, but nearer the road to the east their dip changed to northwest. The ore consisted of alternate layers of quartz and magnetite, forming a finely crystalline aggregate. Two analyses are on record:

Fe=33.91%; P=.028%; SiO_2=about 50%; Authority, N. J. 1876, p. 53.
Fe=54.23; P=.033; S=tr; Ti=tr; Mn=tr; Authority, N. J. 1879, p. 81.

References: N. J. 1873, p. 71; 1876, pp. 52–53; 1879, p. 81; 1880, p. 116; 10th Census, p. 154.

THE HURD MINE BELT.

The Hurd Mine belt begins at Delaware River, runs northeast through Musconetcong and Schooleys mountains, along the east side of Lake Hopatcong and crosses the State line 3 miles west of Greenwood Lake. Through this distance of 60 miles, mine holes are scattered at nearly equal intevals. Most of them, especially those situated on its southwest portion, were never productive, but at one or two points important mines were developed. The most notable of these were the Mt. Olive, the Hurd and the Weldon mines, all of which yielded large quantities of rich ore. None of the ore was of Bessemer grade but it was all fairly rich in iron. In a few of the deposits at the southwest end of the belt titanium was present in considerable quantity, but in the deposits of the northern mines it occurred in such small amounts as to be practically negligible.

(151) *The Hager Mine.*

The Hager mine was 1 mile west of Spring Mills, near the top of the south slope of Musconetcong Mountain, in Holland Township, Hunterdon County.

About 1877 two shafts were sunk 40 feet and from these about 700 tons of ore were raised. The mine was then closed and remained idle until 1879, when it was reopened, to remain open until the latter part of 1880. During this period about 800 tons were mined. The shafts from which this ore was obtained were abandoned in the early part of the year because of trouble with water, and a new one was started further northeast. This, probably, was never completed.

The ore obtained from the surface in the early workings was practically free from sulphur, but with increasing depth there was an increase in the content of pyrite. In the exploration of 1879 a deposit 7 feet wide was encountered at a depth of 60 feet. This dipped southeast. A sample of the ore contained:

$Fe = 56.13$; $S = 7.59$; $P = .29$; $Ti = .84$; $Mn = 0$. Authority, N. J. 1879, p. 63.

The northeast shaft, put down in 1880, struck ore at 20 feet. It was in two narrow deposits separated by two feet of rock. One was 2 feet wide and the other 4 feet wide.

A sample of red soft surface ore, taken from a pile of a few tons at the shaft, gave:

I. $Fe = 62.71$; $S = .093$; $P = .274$. Authority: 10th Census, p. 164.
II. $Fe = 56.39$; $SiO_2 = 6.64$; $P = .19$; $TiO_2 = 7.02$. Authority: N. J. 1879. p. 165.

Analysis II was by the Thomas Iron Cmpany. Other samples gave: $TiO_2 = 5.62\%$ and 4.09%.

References: N. J. 1879, p. 63; 1880, p. 109; 10th Census, p. 164; 1883, p. 122; 1899, p. 165.

Mellick Smith's Explorations.

Mellick Smith's explorations were 1 mile northeast of the Hager mine in Holland Township, Hunterdon County. A shaft, 50 feet deep, dug in 1880 on a line of attraction uncovered only float ore.

The location of this shaft has not been definitely ascertained.

Reference: N. J. 1880, p. 123.

The Alpaugh Explorations.

The Alpaugh Farm explorations are described as being on the Alpaugh estate, 1.25 miles from West Portal and three-quarters of a mile southeast of the Swayze mine, in Bethlehem Township, Hunterdon County. If on the Alpaugh estate as located on the county map of 1873, the explorations were northeast of the Swayze mine, and not southeast, as stated. In this event the pits are on the Ford belt, between the Swayze and the Rodenbaugh mines.

A shaft 25 feet deep was sunk in the 70's, finding a small vein of ore, but the quantity of water encountered was so great that the place was soon abandoned.

Reference: N. J. 1879, p. 65.

(152) Wild Cat Mine.

The Wild Cat mine was in Bethlehem Township, Hunterdon County, about midway between Norton and West Portal, on the north side of the road joining the two places.

The mine was opened about 1876. The vein must have been 8 or 10 feet thick. It consisted of two ore layers, one of which was 4 feet wide, separated by 2 or 3 feet of rock.

The mine was operating in 1879 through a shaft 30 feet deep, but there is no record as to the quantity of ore that was being raised. From the size of the dumps it is evident that considerable work was done.

Reference: N. J. 1879, p. 65.

(153) The Miller Mine.

The Miller mine, or the Miller Farm mine, was 1.25 miles southwest of Glen Gardner, at the junction of the road from this place and that between Hampton Junction and Clinton, in Bethlehem Township, Hunterdon County.

Openings were made in 1871 and thereabouts without finding any considerable quantity of ore. The place was further explored in 1879, but no ore was shipped.

There are supposed to be two veins on the property about 1,000 feet apart. The attraction has been traced northeast through the stone quarry on the north side of the right of way of the Central Railroad of New Jersey and beyond. When examined under the microscope much of the rock in which the ore occurs is seen to be crushed. A part of it appears to be porphyritic in the hand specimen, but in thin section all the porphyritic phases are discovered to be breccias. The ore is, in part at least, in pegmatite.

References: N. J. 1873, p. 56; 1879, p. 66.

(154) *The Maberry Mine.*

The Maberry, or Mayberry, mine was one-half of a mile southwest of Glen Gardner, in Bethlehem Township, Hunterdon County, and about one-half of a mile northeast of the Miller mine, on the road between the Miller mine and Glen Gardner.

It was first opened in 1880, 300 tons of ore were mined, and then the mine was closed.

References: N. J. 1880, pp. 110 and 124; 10th Census, p. 162.

(155) *The Eveland Mine.*

The Eveland mine was near Glen Gardner, in Lebanon Township, Hunterdon County, on the north side of the railroad, between this village and Clarksville.

The place was opened in 1880 by three pits 50 feet apart, and worked for a few months, producing 224 tons of ore. The vein was 5 to 7 feet wide.

It is not known that the mine was ever operated on a commercial scale.

References: N. J. 1880, pp. 110 and 124; 10th Census, p. 162.

An unnamed pit with a moderately large dump is situated about three-quarters of a mile northeast of Glen Gardner, in Lebanon Township, Hunterdon County.

Nothing is known of its history.

(156) *Apgar's Mines.*

These mines are represented on the topographic map of the State as situated about 1 mile northeast of Anthony, in Lebanon Township, Hunterdon County.

The mine holes are four in number, on the north side of the road to Pennville. No description of them has been found anywhere in the literature of the New Jersey mines. There has been considerable work done in the vicinity, but with what result is unknown.

(157) *The Hann Mine.*

The Hann mine was one-half of a mile northeast of Pleasant Grove, in Washington Township, Morris County, on the road from Schooleys Mountain to Washington.

The mine was opened on a strong line of attraction by two shafts in 1871 or 1872. Some lean ore was obtained, and then the shafts were temporarily abandoned. About 1,000 feet further southwest the line was tested again, and again lean ore was encountered in a thin vein, dipping southeast. Shortly afterward the mine was again reopened and worked at intervals until 1880, when it was once more closed. The last work was mainly in the line of surface exploration.

The veins were two in number, striking a little north of east and dipping 30° south-southeast.

During its last period of activity (1879-1880) about 150 tons of ore were raised, making the total production at the time the mine was abandoned about 5,000 tons.

An analysis of an average sample of the ore raised about 1879 yielded:

$Fe = 56.97$; $S = .088$; $P = .367$; $Mn = 0$; $TiO_2 = 1.05$. Authority: N. J. 1879, p. 67.

References: N. J. 1873, p. 57; 1879, p. 67; 1880, p. 111; 10th Census, p. 162.

(*158*) *The Hunt Farm Explorations.*

The Hunt Farm explorations were a mile southwest of Schooleys Mountain, near the Pleasant Grove road, in Washington Township, Morris County.

Ore was discovered here while digging a well and a cellar, but the prospects were not sufficiently favorable to warrant explorations.

Reference: N. J. 1879, p. 67.

(*159*) *The Derrenberger Farm Explorations.*

The Derrenberger Farm explorations were on Schooleys Mountain, in the settlement of the same name, in Washington Township, Morris County.

This mine was opened in 1883 on a brown granular ore, which changed to the usual blue ore at a depth of 30 feet. The vein was 4 or 5 feet wide. Some ore was shipped, but in what quantity is not known. The mine seems to have been operated for part of a year.

Reference: N. J. 1883, p. 125.

(*160*) *The Stoutenburgh Mine.*

The Stoutenburgh mine was located about one-half a mile northeast of Schooleys Mountain, in Washington Township, Morris County.

The mine was first opened in 1872, and worked during this year and the succeeding one, yielding 6,700 tons of ore. It was then closed down and not reopened until 1877, when ore was found in nine trial pits situated southwest of the old mine. Two shafts were sunk 35 feet apart and about 350 feet southwest of the old mine. These were operated until 1880, producing 1,680 tons. After this work ceased, except for the deepening of one of the shafts 50 feet. In all the openings the mine was very wet.

The deposit first developed measured 5 feet to 9 feet thick, and dipped 35°–40° south-southeast. At a greater depth and further to the southwest the dip was reported to be northwest. In 1873

the mine produced at the rate of 5,000 tons annually. The vein diminished to 2 feet in width, however, and this led to its abandonment.

To the southwest the explorations of 1877 discovered a vein of lean ore from 1 to 7 feet thick, with a dip southeast, which became steeper with depth. The foot-wall was well defined, but the hanging-wall was irregular.

Two analyses of the ore have been recorded. The first is that of material taken from a depth of 40 feet in the old mine, and the second that of the ore of the newer mine.

	SiO_2	Fe_3O_4	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	Total	Authority
I.	6.70	83.04	3.87	3.25	.86	.10	1.92	.70	= 100.44	N. J. 1873, p. 58
		$Fe = 60.13$; $S = .096$; $P = .839$								
II.		$Fe = 56.37$; $S = .155$; $P = .639$								10th Census, p. 162

Northeast of the old mine a smaller vein was discovered, but the ore, though rich, was very narrow. North of the mine was still another vein, from which 40 tons of ore were recovered. Another vein, 5 feet wide, was found a few rods east of the old mine, and on its west side a fourth vein, 3 or 4 feet wide, was opened for a length of 70 feet. Both of these were reached by shafts. In the fields to the east are two lines of attraction, and these are taken to indicate a still farther extension of the vein in this direction. The whole neighborhood seems to be underlain by small deposits.

References: N. J. 1873, pp. 57–58; 1879, pp. 67–68; 1880, p. 111; 10th Census, pp. 161–162; 1883, p. 125.

(154) The Hunt Farm Explorations.

Explorations made 1 mile northeast of Schooleys Mountain, in Washington Township, Morris County, also disclosed a little lean ore.

Several pits were dug here between 1874 and 1879, and 30 tons of ore were mined. Although the mine is reported to have been leased in 1879, nothing more has been heard of it.

Reference: N. J. 1879, p. 69.

THE MOUNT OLIVE MAGNETIC BELTS.

The Mount Olive mines are near the southwest end of a comparatively wide belt of attraction, which, because of its length and width, is one of the notable features of the Highlands in New Jersey. The belt begins a short distance north of the South Branch of the Raritan River, and extends uninterruptedly for a distance of 5.5 or 6 miles to within three-quarters of a mile of the south end of Lake Hopatcong. Its width averages about 800 feet, with a magnetic declination (or dip) of from 8° to 90°. It has been opened at a number of points by shafts, tunnels and pits, which are sufficiently near together to show that the entire belt is underlain by ore. Some of the openings were formerly important mines, but on the whole the ore was lean. The best known mines on the belt were the Mt. Olive, the Drake, the Salmon, the Osborne, the Church and the Hilt.

A second belt, about a mile southeast of the Mount Olive belt, may be designated the South Mount Olive belt. It begins at the Hopler mine, runs northeast for about 5 miles parallel to the Mount Olive belt, and terminates just south of the Church mine. Its width averages a little less than that of the northern belt, and the strength of the attraction is less. The southern belt has been less thoroughly explored than the northern one, and no important mines were ever developed upon it. The ore found was so lean as to be unmerchantable.

These two belts, with a length of 5.5 miles and an aggregate breadth of about 1,500 feet, are regarded as evidence of the existence of a great quantity of magnetite in the rocks over which the attraction is observable. So far as we know, the magnetite is pretty uniformly distributed, forming a lean ore, which will need concentration before being marketable. There are probably no large rich ore bodies in the area, but the quantity of lean ore present must be enormous.

On the east side of Turkey Brook, near Mount Olive, there are numerous openings within the belt of magnetic attraction referred to in the preceding paragraph as the north Mount Olive belt. Some of these openings are very old, many of them having

been made long before 1855. Although it is difficult to identify all the mines referred to in the various reports of the Survey, the location of the most important ones is established fairly satisfactorily. The mines described in the Report for 1855 were the Osborne, the Drake and the Stevens mines. In later reports brief descriptions are given of the Solomon, Chas. Solomon, Wm. Stevenson and several unnamed openings. Later we read of the Mt. Olive mines and the Salmon mine. As a matter of fact, the entire magnetic belt for a distance of 3 miles from its southwest end was thoroughly explored by test pits and shafts that were so closely placed as to leave no doubt but that the entire strip of country along the east side of Turkey Brook is underlain by a series of short parallel veins of lean ore.

The most important openings beginning at the southwest were on the Stephens, Drake, A. L. Salmon and Chas. Salmon property. They are referred to in the literature by the names of the land owners. All these openings were between the South Branch of the Raritan River and the road from Mount Olive to Flanders. North of this road a few hundred feet was an important group of shafts and a tunnel, which is thought to be the Drake mine referred to in the early State reports.

The Crane Mine.

The southernmost pit in this belt that is referred to in print was the Crane mine, which is reported as being about one-quarter of a mile south of the Stephens mine.

The mine was opened a few years prior to 1868, but probably never produced much ore. It is noteworthy because of the presence of uranium compounds in its ore. Specimens obtained from its dump-heap contained yellowish-green scales of uranite coating feldspar and magnetite, and small quantities of uranocher and gummite. The ore was of two kinds, of which one was blue and had a bright luster, and the other was a dull black variety.

Reference: N. J. 1868, p. 602.

(161) The Stephens Mine.

The Stephens mine was about one-half a mile southwest of the Drake mine, and about the same distance south of Mt. Olive. The ore was first discovered at this place in 1848. In 1855 the vein had been opened by a shallow pit through a length of 90 feet. At the bottom of the pit, which was only 15 feet deep, the ore was so filled with pyrite that it was practically worthless, and consequently the place was abandoned. The iron content of the ore is reported as being between 63 per cent. and 68 per cent. The property was later operated as a portion of the Mt. Olive mines.

References: N. J. 1855, pp. 177–178; 1868, p. 597–8.

(162) The Mount Olive Mines.

The early explorations between the Stephens and the Drake mine uncovered a practically continuous vein between the two mines. The most promising of these were the pits on the property of John Drake, of Wm. Salmon and of Chas. Salmon. Later they were consolidated under one management and operated as the Mount Olive mines.

The first pit on the Drake property was dug in 1848. The openings on Salmon's land were a few yards northeast of the Drake pits. They were probably dug between 1855 and 1868. A few hundred yards northeast of these were the explorations on Chas. Salmon's land. These revealed two parallel seams of ore close together. They were very narrow, the northwest one measuring 4 inches in width and the southeast one 12 inches. The latter dipped 70° southeast and carried 61.2 per cent. of iron.

In 1872–3 the Salmon mine was worked but all others had been abandoned. The Salmon mine was again explored in 1874–5, and the mine on the Drake lands was worked to a slight extent. The principal vein at the Salmon mine was found to dip 35° to 45° southeast, and the ore shoots to pitch northeast. The average thickness of the ore had increased to 10 feet. At the old mine on the Drake land three veins were found, of which

only the central one was mined. In 1879 both of these mines were leased by one party and preparations were made to work them together. They were operated during the first half of 1880 under the name of the Mt. Olive mines, producing 1,625 tons. They were then closed because of the slack demand for ore. The total production to this time was estimated at 22,400 tons. The main shaft, when work ceased, was 165 feet deep and the vein was 6 to 8 feet wide. A new shaft, sunk to the northeast of this one, was down 35 feet when work was stopped.

The mines were reopened in 1883 and two shafts 100 feet apart were operated. By this time the vein had been worked a distance of 400 feet, and to a depth, in some places, of 175 feet. Its average width was 5 or 6 feet, although in a few places it measured 27 feet in breadth. A new shoot was discovered in this year and a new slope 175 feet long was sunk on it. The deposit dipped 35° to 40° southeast, and was crossed by a fault that threw the vein to the right. All the mines were closed in 1886.

At the present time (1908) an attempt is being made to open up the country to the east of the mines by a company with a large capitalization. It is stated that a great quantity of ore of good quality exists in the area, but the evidence upon which the conclusions are based is not given. Apparently no explorations have been undertaken by the promoters of the project, and no data are therefore at hand from which a reasonable estimate of the quantity of ore in the ground can be calculated.

All the ore of the vein contained considerable limonite, and a great deal of pyrite, which was altered by downward percolating water and changed to limonite. The explorations showed clearly that there are in this place a number of small deposits arranged in lines. Pegmatite appears to have been abundant in all the mines, probably much of the ore being a magnetitic pegmatite.

Samples from 600 tons at the old shaft (1) and of 75 tons of oxidized surface ore (2) at the new shaft (1880) gave:

1.—$Fe = 58.92$; $S = 1.96$; $P = .182$. Authority: 10th Census, p. 161.
2.—$Fe = 63.36$; $S = .145$; $P = .090$. Authority: 10th Census, p. 161.

References: N. J. 1855, pp. 175–9; 1868, pp. 597–602; 1873, p. 59; 1879, pp 70–71; 1880, p. 112; 10th Census, p. 161; 1883, p. 127; 1884, p. 97; 1886, p. 148.

(163) *The Solomon or Salmon Mine.*

The Solomon, or Salmon, mine was immediately northeast of the Mount Olive mine, in Mount Olive Township, Morris County.

The first account found of this mine appears in the Annual Report for 1886. The mine was probably opened about this time. It was operated in this year on a 5-foot-wide ore body that dipped 42° southeast and pitched 10° northeast. The ore was an extension of that worked in the Mount Olive mine. The yield was about 300 tons monthly.

There is only one reference to this mine in the literature. Its location is not definitely described, so that it is impossible to identify it. It was probably never important.

Reference: N. J. 1886, p. 151.

(164) *The Drake Mine.*

Drake's mine was about one-half a mile northeast of the Stephens mine at Mount Olive, in Roxbury Township, Morris County, and 2 miles southwest of Hilts mine, a short distance north of the road between Mount Olive and Flanders. It is probably the opening in the north side of this road.

The mine was first opened in 1854 on a vein 5 feet thick, dipping southeast 45°. By 1855 it had been explored for a length of about 100 feet and to a depth of 18 feet, but it was not at that time being operated.

Later a tunnel was driven southeast into the hillside from the level of Turkey Brook, a distance of 700 feet. It cut five ore veins, all dipping between 50° and 65° southeast. The northwest vein was 5 feet wide and the others 5 feet, 3 feet, 8 feet, 4 feet and 3.5 feet, respectively. The ore varied between 37 per cent. and 51 per cent. in iron, and the rock through which the tunnel passed averaged 20.5 per cent. of metal.

From the nature of the work done it is evident that the place was thought to promise well.

The ore raised in 1868 averaged:

Fe_3O_4	*SiO_2 and ins.*	*S*	*P_2O_5*	*Met. Iron*	*Authority*
88.4	8.0	.0	.0	64.0	N. J. 1868, p. 599.

References: N. J. 1855, p. 177; 1868, p. 599.

(165) The Salmon Mine.

About one-quarter mile south of the road running east from Budds lake to the Main Flanders-Stanhope road are seven or eight pits from which lean ore was obtained about twenty-five years ago. On the topographic map they are designated as the Salmon mine, but no reference to this location has been found in the literature. The pits are on the main line of attraction passing through the Mount Olive and Osborne mines, but so far as is known none of them ever became shipping mines.

(166) The Osborne Mine.

The Osborne mine was 3 miles from Stanhope on the road to Mount Olive and about one-half mile northeast of the Salmon mine. At the present time there can still be seen six or seven large pits, of which all but two are on the east side of the road, and the remains of an old shaft.

The mine was opened in 1848 on a deposit 15 feet wide. Before 1855 this had been worked to a depth of 20 feet for a distance of 50 feet. The dip of the deposit was 45° southeast. Operations were suspended before 1855 because of the difficulty of getting rid of water.

An analysis of the ore made in 1868 indicated the presence of 66.2 per cent. of iron.

References: N. J. 1855, p. 176; 1868, pp. 599-600.

(167) The Stephens Mine.

Several pits situated on the farm of Mr. Stephens, a few hundred yards northeast of the Osborne mine, are known locally as the Stephens mine. They are on the same line of attraction as that passing through the Osborne mine, but there is no record of any ore being obtained from them.

(168) The Baptist Church Mine.

The Baptist Church mine was a few hundred yards southwest of the Hilt mine, in Roxbury Township, Morris County, and about three-quarters of a mile northeast of the Osborne mine.

The openings, of which there were six or seven, were situated on the west side of the road between Mt. Olive and Ledgewood, in the same vein as the Hilt mine. Several hundred tons of ore were raised about 1873, but further than this nothing is known of the mine.

Reference: N. J. 1873, p. 59.

(169) The Hilt Mine.

The Hilt mine was about 2.5 miles southeast of Netcong, in Roxbury Township, Morris County, on the northwest side of the road from Mount Olive to Ledgewood, and a few hundred yards northeast of the Church mine.

It was opened in 1854 on a vein 5 or 6 feet wide where first struck. This dipped 75° southeast. A shaft was sunk a few years later, and this had reached a depth of 25 feet in 1868. Five or six pits and the ruins of the old shaft are still discernible.

The composition of the ore was as follows:

Fe_3O_4	SiO_2 *and ins.*	*S*	P_2O_5	*Met. Iron*	*Authority*
80.8	10.8	.9	.0	58.5	N. J. 1868, p. 600
79.7	14.6	.0	.0	57.7	N. J. 1868, p. 600

References: N. J. 1855, p. 177; 1868, p. 600.

(170) The Willets Mine.

The Willets mine was one-half mile north of the Hilt mine, in Roxbury Township, Morris County, on the west side of the road between Mt. Olive and Shippenport.

The mine was probably nothing more than an exploration. It consists of two pits situated in the belt of attraction that stretches southwest and surrounds the Mt. Olive mines, but it is not certain that any ore was ever obtained from it. If any ore was found, it was probably lean. The attraction near the mine holes is fairly strong, but at a very short distance from them it is only moderately high.

(171) The Wilkinson Mine.

The Wilkinson mine was northeast of the Willets mine, just across the road. The conditions here were probably the same as

at the Willets mine, though nothing is known as to the amount and quality of the ore discovered. There were three pits in an area characterized by a moderately strong attraction.

OTHER MINES IN THIS BELT.

The other mines in the Hurd mine belt are scattered at comparatively wide intervals on isolated lenses except in the case of the Weldon mines, which are on a vein in which are several lenses, apparently connected with one another.

(172) the Wolf Mine.

The Wolfe, or Wolf, mine was about 1.5 miles south of Netcong, on the east side of the road to Flanders, in Mt. Olive Township, Morris County. It was situated about a mile west of the Mt. Olive belt of attraction, apparently on an isolated ore body. It is referred to in this place only as a matter of convenience.

The mine was first opened about 1880. It was reopened in 1901, and 500 tons of ore were mined. The vein was so small, however, that work soon ceased. The ore contained about 59 per cent. of iron, traces of sulphur, and a small proportion of phosphorus, although it was above the Bessemer limit.

Reference: N. J. 1901, p. 138.

(173) The Lake View Mine.

The Lake View mine was within 100 yards of the shore of Lake Hopatcong, in Roxbury Township, Morris County, and about one-quarter mile west-northwest of the Lake View house.

This is another old ore location. Openings were made about 1863, but their history has not been learned. The place was opened again under the name given above in 1882, and was worked for a brief period and was then abandoned.

Three shafts were put down during the later operations, and at least one shaft and a large pit were opened during the earlier period of activity. The newer shafts were 85, 84 and 60 feet

deep, opening up 150 feet of the vein. The width of the deposit averaged 6 feet. It dipped southeast except at one point (in the old open pit), where the walls were vertical.

The ore was rich but contained sulphur. The foot-wall was clean but on the hanging-wall side ore and rock were mixed.

Reference: N. J. 1883, p. 129.

(174) Nolan's Mine.

Nolan's, or Noland's, mine was on Nolan's Point, on the east side of Lake Hopatcong, Jefferson Township, Morris County.

It was opened before 1855 and worked to a depth of 45 feet and for a depth of 500 feet. The deposit was 3 or 4 feet thick and dipped 70° southeast. The mine was evidently abandoned before 1868, and, so far as can be learned, has not been reopened since.

References: N. J. 1855, p. 169; 1868, p. 603; 1879, p. 71.

(175) The Hurdtown Apatite Mine.

The Hurdtown apatite mine was once very celebrated as being a supposed promising source of phosphatic material. It was situated in Jefferson Township, Morris County, about three-quarters of a mile southwest of the Hurdtown mine, on the north side of the road between Hurdtown and Nolan's Point.

The mine was opened and abandoned some time prior to 1855. The ore is a pyritiferous magnetite, containing a large proportion of apatite. Pyrrhotite, calcite and the usual silicates were also intermingled with the magnetite, in some specimens in large quantity.

The apatite occurs in irregular seams, often intermixed with pyrrhotite and in crystals embedded in this mineral. It is green, amber or brown, sometimes transparent, sometimes opaque. Occasionally it is in distinct crystals with hexagonal cross-sections and rounded edges. In some cases the apatite is in large masses that are almost pure, but usually it is in aggregates mixed with all the other minerals mentioned. The pyrrhotite is also abund-

ant, occurring sometimes in masses several inches in diameter. Frequently it is pure, but more often it includes grains of apatite.

The magnetite is often found embedded in the pyrrhotite as nodules. It possesses a perfect cleavage into thin plates, the surfaces of which are often striated. In this form it was supposed by those who have studied it to be pseudomorphic after the pyrrhotite. The mineral was also found embedded in apatite, and also in aggregates with the silicates. The pyrite was in quite large quantity, but it was not as abundant as the pyrrhotite.

Although apatite is present in comparatively large quantity, the ore is not sufficiently rich in the phosphate to warrant its being utilized as a source of this material.

References: N. J. 1855, pp. 166–168; 1868, pp. 603–606; 1879, p. 71.

(176) The Hurd Mine.

The Hurd, or Hurdtown, mine was formerly one of the best known mines in the State. It was situated about 6.5 miles north-northwest of Dover, on the road between this city and Sparta.

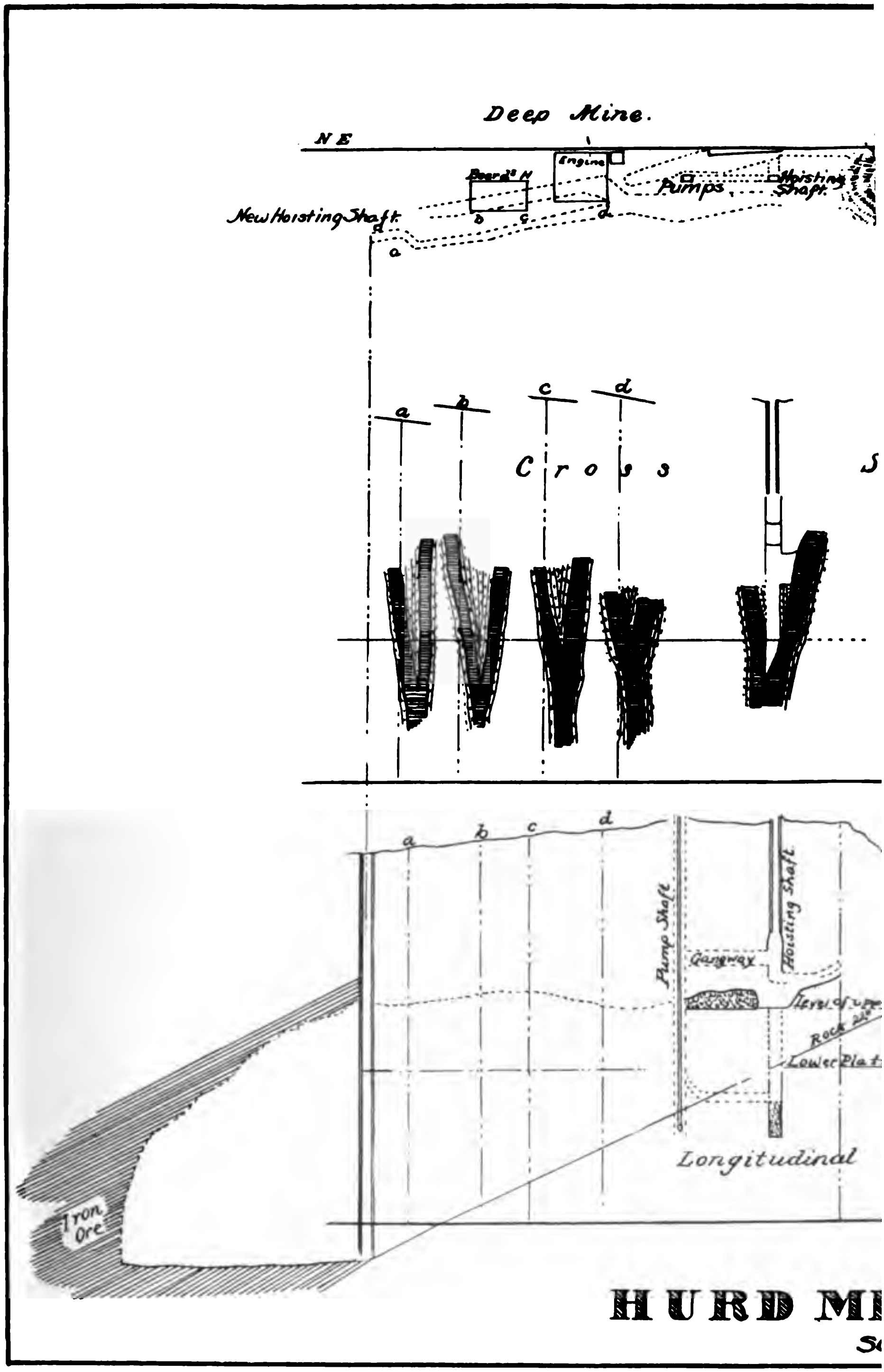
The mine was worked for a long time previous to 1855, but was not in operation in this year. In 1868, however, it was producing at the rate of 20,000 tons annually. A figure exhibiting the condition of the working at this time is reproduced in Plate VI. The mine continued in operation for many years almost uninterruptedly, until it was finally permanently abandoned in 1903. Its total production to June, 1880, was estimated at more than 500,000 tons. In 1890 work was suspended for a few months pending the readjustment of the lease, but it was again resumed a few months later. In 1895 the ore began to fail. The bottom workings were abandoned, and the mining was confined to the pillars and other supports left in the old workings. Between 1895 and 1898 the yield was about 2,400 tons annually. During the latter year most of the remaining ore was removed. Searches were made by diamond drill for new deposits, but only small seams of ore were found beneath the bed of the old shoot, at a depth of 600 feet from the surface. Explorations in other directions were also unsuccessful, and the mine was practically abandoned after reaching a vertical depth of 2,600 feet, *i. e.*, 1,600

below tide, and a depth measured on the slope of 6,000 feet. In the succeeding year further explorations were made, likewise without success, and about 2,500 tons of ore were removed from old pillars. Explorations were continued through 1900 and 1901. In the latter year a new shoot 9 feet wide was discovered south of the fault, to be referred to later, and west of the three shoots that had so long furnished ore. This was reached at a depth of 175 feet. Some ore was obtained from this, but most of the 8,000 or 9,000 tons produced during the year came from the old workings. In the following year 14,000 tons were taken from the fourth shoot on the west side of the southwest mine and from a deposit on the hanging-wall side of the openings near the road, which had been located by previous explorations. All work ceased in 1903.

Originally there were two principal workings from which ore was obtained. The northeast one was called the "deep" mine, and the southwest one the "level" mine, Turnpike mine, South Vein mine and Bluff mine in its different parts. (See Plate VI.) There was no connection between the two and no explorations had been made between them to learn the relations of the two ore bodies. From the fact, however, that in both openings the ore was in a curved deposit, like a fold, with practically the same dimensions, it was early thought that the two mines were separated by a cross fault, with the upthrow on the northeast side.

At the southwest end of the property is an old open working, indicated on the vertical section as "fallen surface." On the northeast wall of this the ore is reported to have presented the appearance of a fold (see Fig. 6, page 138), with its southeast line nearly vertical and its northwest line dipping 45°–60° southeast. The bottom of the fold pitched northeast at 26° to 31°, and was followed by a slope, which finally reached a length of 6,000 feet. The South Vein mine and the Bluff mines were on the southeast limb, and the Level mine was on its northwest limb.

The Deep mine, which was northeast of the supposed fault, was presumably on both limbs, as the ore-body worked by it was Y shaped. It differed from the ore bodies in the southern workings in continuing below the point of junction of the two limbs, as though the deposit were a branching vein with a horse of rock



PLAN AND SECTIONS OF HUR

separating its two branches. The pitch of the trough was a little flatter than in the southwest mines. Moreover, the axial plane of the ore body was tilted further to the northwest than in the Southern mines, so that the northwest limb dipped 75° to the southeast and the southeast limb was nearly vertical. The deposits on the west flank of the "fold" appear not to have been worked in the northeast mines.

During the long time that the mine was worked the shoot maintained its general character unchanged, except that while in the upper workings the ore and wall-rock graded into one another, in the lower workings the two were sharply marked off from one another, and the wall was exceptionally clean. The cap, bottom and wall rocks completely enclosed it, so that it appeared as an oblique chimney of ore. Its height varied from 60 to 90 feet, and its breadth 35 feet. Thin layers of rock projected from the cap into the ore shoot, but the bottom rock appeared to be uninterrupted. A horizontal section of the mine as it existed in 1882 is shown in figure 16.

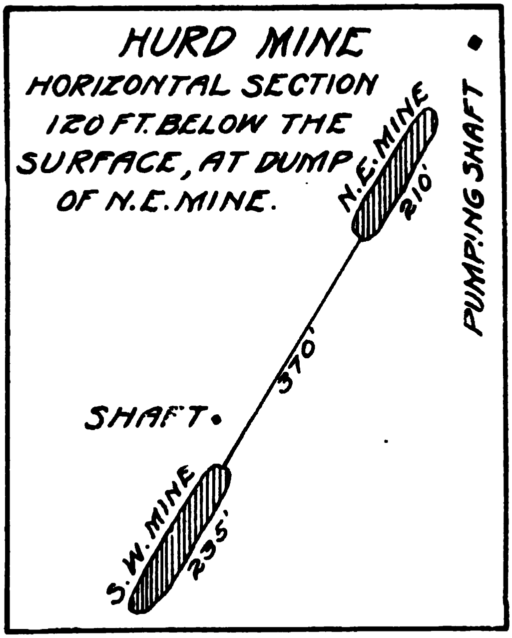


Fig. 16.

Horizontal section of the ore-bodies at the Hurd mine, Hurdtown. (From Ann. Rep. 1883, p. 68.)

During 1884 an offset was encountered, which threw the deposit 12 to 16 feet to the right. In the early description of the ore body there is reference made to a dike dislocating it, but the position and character of this dike are not specified.

The side shoot that lay to the southeast of the main ore-body in the northeast mine was peculiar in shape. Near the surface it measured 5 feet in width and only 4 or 5 feet in height.

The ore obtained from the different portions of the deposit was very varied. In some places it contained considerable apatite, and in others much pyrite in films coating joint cracks. Chalcedony was also abundant in some places as yellow mammillary incrustations on the walls of fissures in the ore and also as irregular masses enclosed in magnetite. It was also found lining geodes in smoky quartz. Translucent quartz cut by strings and seams of magnetite were also met with, and masses of ore cut by narrow seams of white quartz.

Analyses of the ore made in 1875 gave:

	Fe_3O_4	SiO_2	Al_2O_3	Mn_2O_3	MgO	$CaCO_3$	S	P_2O_5	Total	Authority
I.	85.88	7.90	2.14	.21	.36	2.95	.06	.48	=99.98	N. J 1885, p. 105
II.	92.01	3.81	1.00	.23	.25	2.19	.02	.44	=99.95	N. J. 1885, p. 105

No. 1. $Fe = 62.195$; $P = .209$; $S = .06$

No. 2. $Fe = 66.63$; $P = .192$; $S = .02$

The result of a complete analysis of a sample taken from 17 carloads is given on page 112. The equivalent iron, sulphur and phosphorus contents are:

$Fe = 66.02$; $P = .196$; $S = .169$; Authority: 10th Census, p. 157.

References: N. J. 1855, pp. 165–166; 1868, pp. 606–610; 1873, p. 65; 1879, p. 72; 1880, p. 112; 10th Census, p. 157; 1882, p. 70; 1883, pp. 67–69 and 129–130; 1884, p. 98; 1885, p. 105; 1886, pp. 144–145; 1890, p. 57; 1891, pp. 239–240; 1896, pp. 324–325; 1897, pp. 319–320; 1898, pp. 233–234; 1899, p. 152; 1900, pp. 199–200; 1901, pp. 138–139; 1902, p. 118.

(178) The Weldon and (177) Lower Weldon Mines.

The Weldon and Lower Weldon mines were situated in Jefferson Township, Morris County, about 1.5 miles northeast of the Hurd mine, and about 1.75 miles south of the Dodge mine, on the road between Woodport and Lower Longwood. The Lower Weldon adjoined the Weldon mine on the southwest.

The openings of the two mines extend for a half mile along the road (Fig. 17) as a series of pits and shafts, most of which are now in a tumbled-down condition.

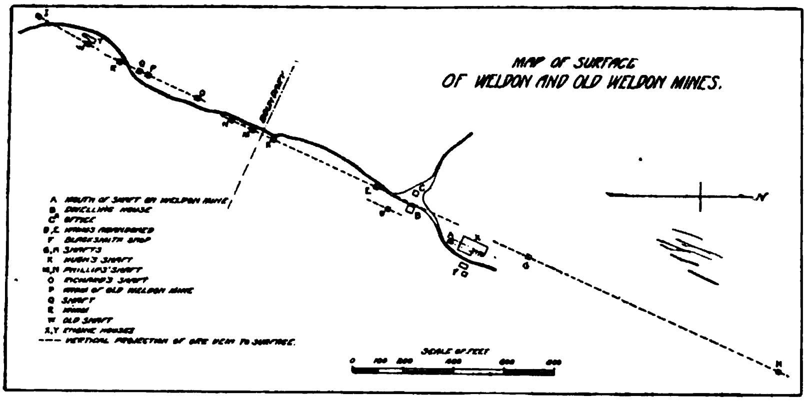


Fig. 17.

Surface map of Weldon and Old Weldon mines.

The Weldon mine was opened in the early part of the last century, and had been worked extensively before 1855. In 1868 the mine had been abandoned, and the openings were, consequently, full of water. A few years later it was reopened, and in 1873 was being operated. In the following year the mine was again closed, and it remained idle for six years. In 1880 it was again reopened and worked until the ore shoots began to pinch and diverge, when operations again ceased. The mine was reopened in 1885 and worked during the early part of 1886, when it was again closed. It was once more reopened in 1888, and worked until 1890. At this time a concentrator was erected to remove the phosphorus from the rich ore and concentrate the lean ore so that the whole might be sold as of Bessemer grade. By the end of 1891 a shaft had been sunk 300 feet. This encountered three new ore-shoots separated by rock layers from 8 to 30 feet thick. The concentrator separated about 2,000 tons of ore during the year with such success that a second one was erected during the succeeding year. By 1896, however, the entire plant was abandoned, because of the expense of preparing

the ore for market. It is reported to have been at work in 1899, but was idle in 1900. In 1901 the mine was again operated in a small way for a few months from a shaft near the southwest property line, yielding about 250 tons of ore. During the course of the operations a small offset was encountered which threw the vein its own width. The water in the old workings was tapped and the new workings were flooded, causing all work to cease. In 1902 the mine changed hands. It was unwatered and 4,000 tons removed. It was then shut down because of the coal strike. It has not been operated since.

The Lower Weldon mine was on the same vein as the Weldon. It is not known when it was opened, but it was being operated in 1873. It was closed a few years later, and was idle in 1879. The mine was again working in 1890, when it was 360 feet deep, but it was abandoned before 1896. In 1901 a little exploratory work was done, but so far as known no ore was raised.

The ore body exploited in 1868 at the Weldon mine was from 4 to 7 feet wide, and had been worked for about half a mile in length by narrow open pits. Its dip was 50°–75° southeast. The main workings were at the northeast end of the vein. Here there were two shoots of ore lying side by side, dipping 75° southeast, and pitching 30°–32° northeast. Their height was about 30 feet. The width of the west shoot was 3–4 feet and of the east one 4–5 feet. (Fig. 18.)

As the mine increased in depth the shoots approached, and in the bottom of the mine in 1872 they were only 7 feet apart. Vertical cross-sections of the two shoots, showing their relative positions, are reproduced in Fig. 18. At the shaft the shoots were 29 feet apart at a distance of 80 feet from the surface, while 200 feet northeast of the shaft they were only 7.5 feet apart. When the mine was reopened in 1880 it was found that the shoots were beginning to diverge and to pinch. Consequently, work was stopped after a few months' work.

When work was resumed in 1888 a new shaft was sunk. By the end of 1891 this had reached a depth of 300 feet, and had penetrated the three new shoots of ore which have already been referred to. These shoots varied in height from 20 to 60 feet, and in width from 2 feet to 9 feet. They pitched northeast at

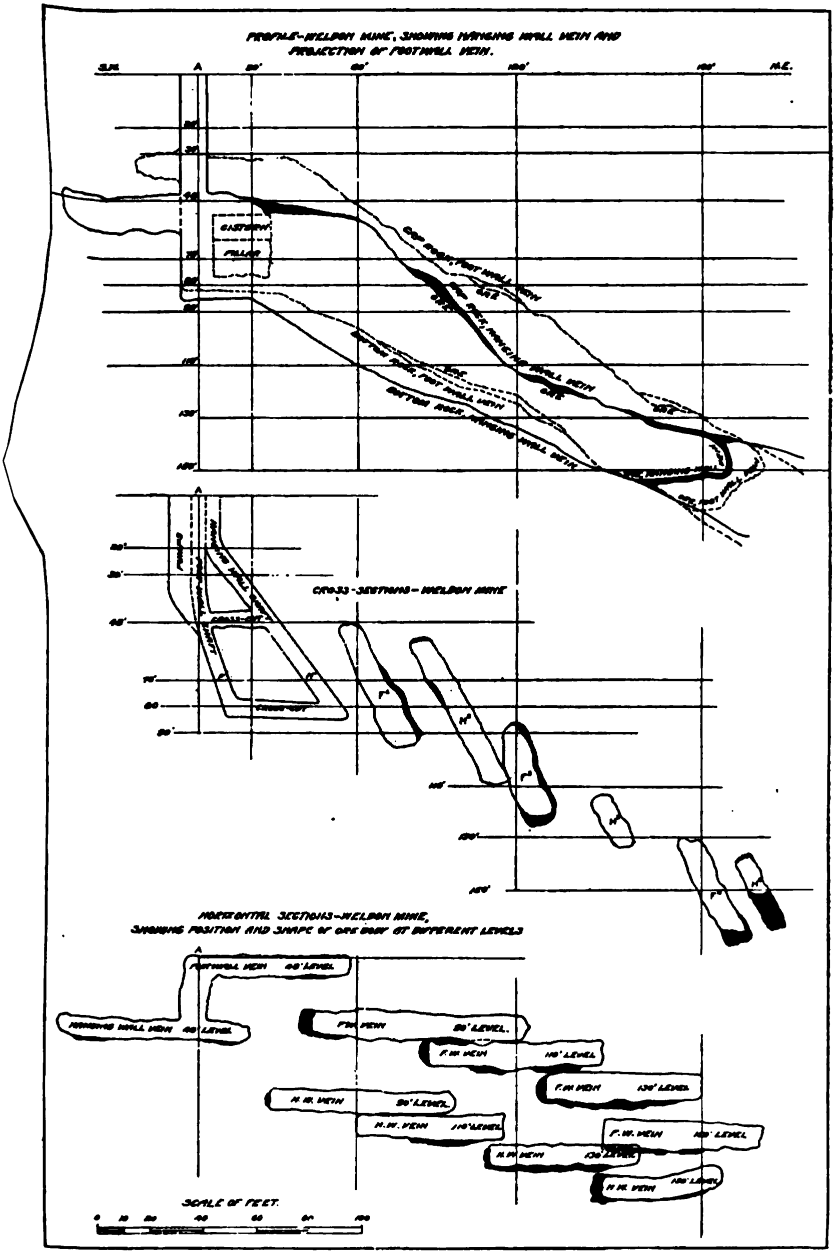

PROFILE—WELDON MINE, SHOWING HANGING WALL VEIN AND
PROJECTION OF FOOTWALL VEIN.
CROSS-SECTIONS—WELDON MINE
HORIZONTAL SECTIONS—WELDON MINE,
SHOWING POSITION AND SHAPE OF ORE BODY AT DIFFERENT LEVELS
SCALE OF FEET.

Fig. 18.

30° and dipped southeast at 50°. The ore of these was non-Bessemer, and averaged 58 per cent. to 60 per cent. metallic iron.

The shoot at the Lower Weldon was very regular. It dipped 50° southeast and pitched 30° northeast. It was about 6 feet to 8 feet wide and carried about 3 feet of clean ore yielding about 58 per cent. of iron. Rock and ore were beautifully interbanded, the former being very micaceous. There were evidently two shoots, one above the other. The upper one was exhausted in 1891. The lower shoot, which was 4 feet wide and 25 feet high, was worked until the mine was abandoned in 1896.

The ore of both mines was lean. It is described as containing quartz, feldspar and apatite. An analysis gave:

Fe_2O_3	Al_2O_3	CaO	SiO_2	P_2O_5	*Alk. Chlorides.*	H_2O	*Total*	*Authority*
86.4	6.1	1.9	3.7	.3	.5	.5	= 99.4	N. J. 1868, p. 612

A sample of a pile of 300 tons of the ore raised in 1880 yielded:

$Fe = 54.80$; $P = .554$; $S = .266$. Authority: 10th Census.

No data are available as to the total production of this mine. During 1870, 1871 and 1872, while under lease to the Thomas Iron Company, 6,639 tons were mined.

References: N. J. 1855, p. 165; 1868, pp. 610–612; 1873, pp. 65–66; 1879, p. 72; 1880, p. 112; 10th Census, p. 157; 1883, pp. 72 and 130–131; 1886, p. 152; 1890, pp. 58–59; 1891, pp. 240–241; 1896, p. 325; 1900, p. 199; 1901, pp. 139–140; 1902, p. 119.

The Clinton Furnace Tract.

Beyond the Weldon mine there are no openings in this belt until the Clinton reservoir is reached. Here there was an old opening on the Clinton Furnace tract, but its exact location has not been discovered. It is reported as being a mile northwest of the old furnace in West Milford Township, Passaic County.

Mining was actively prosecuted here in very early days. The place was reopened in 1872, the old shafts were cleaned out, trenches were cut and ore was discovered in abundance. It, however, contained pyrite and quartz. The deposit dipped 85° southeast.

No work was done other than the cleaning up of the place.

Reference: N. J. 1879, p. 82.

Between the Clinton reservoir and the State line in West Milford Township, Passaic County, the topographic map shows the location of nine openings, of which three are unnamed. Of the others the House and the Sigler mines are not referred to in any of the State reports.

The House mine was situated about three-fourths of a mile northeast of the northwest corner of Clinton reservoir, formerly Buckabear Pond. It has not been visited and nothing is known as to its extent or the quality of its ore. It is near the southwest end of a narrow belt of attraction that has been traced for a distance of a little more than 3 miles to a point one-half of a mile northeast of the northernmost opening of the Utter mine. (Plate VII.) The attraction is fairly strong at several places, but explorations have exposed very lean ore. The most important openings on the belt are those of the Rutherford, the Sigler, the Wallace and the Utter mines.

(179) The Rutherford Mines.

The Rutherford mines comprise a series of four shafts and twelve or thirteen pits, situated on an old road running along the west slope of the ridge immediately west of Cedar Pond. The southernmost shaft is about 1,250 feet south of the oil pipe line which crosses the mountain between Cherry Ridge and Cedar Pond.

There is no description of these openings in the literature, unless the reference to the "Rutherford explorations north of Buckabear Pond" applies to them. This reference states that "in 1888 a shaft was sunk on the Rutherford estate north of Buckabear Pond. The shaft was 100 feet deep but failed to strike a great body or ore." If this is the place in question a great deal of new exploration must have been undertaken at a later date, and a fair amount of ore must have been discovered, for the dump-heaps are large and contain a great quantity of lean ore, besides some which looks quite rich. Mr. Velzo Utter, who resides in the neighborhood of the mine, states that it was originally worked to supply the Clinton furnace, and later (about 1890) was operated for the Franklin company. He declares that the vein

is 12 feet thick and that operations ceased because of the cost of transporation to the furnace. The scant width of the belt of attraction, however, suggests a narrow vein of good ore or a fairly wide one of lean material.

Reference: N. J. 1890, p. 69.

(181) The Wallace and (180) the Sigler Mines.

These mines are on the opposite sides of the west branch of the stream that flows along the west side of the main road that passes through Uttertown. The mine holes are about one and a half miles northeast of the northwest end of Clinton reservoir and about one-third of a mile northeast of the northeast pits of the Rutherford mine. Both the Sigler and the Wallace mines show large dump-heaps, on which the rock and ore are practically alike. The Sigler mine is not referred to in the literature. It is about of the same age as the Wallace mine and its ore is similar. It is reported by residents in the vicinity that when active it shipped 20 or 25 carloads of ore obtained from a drift 300 feet long.

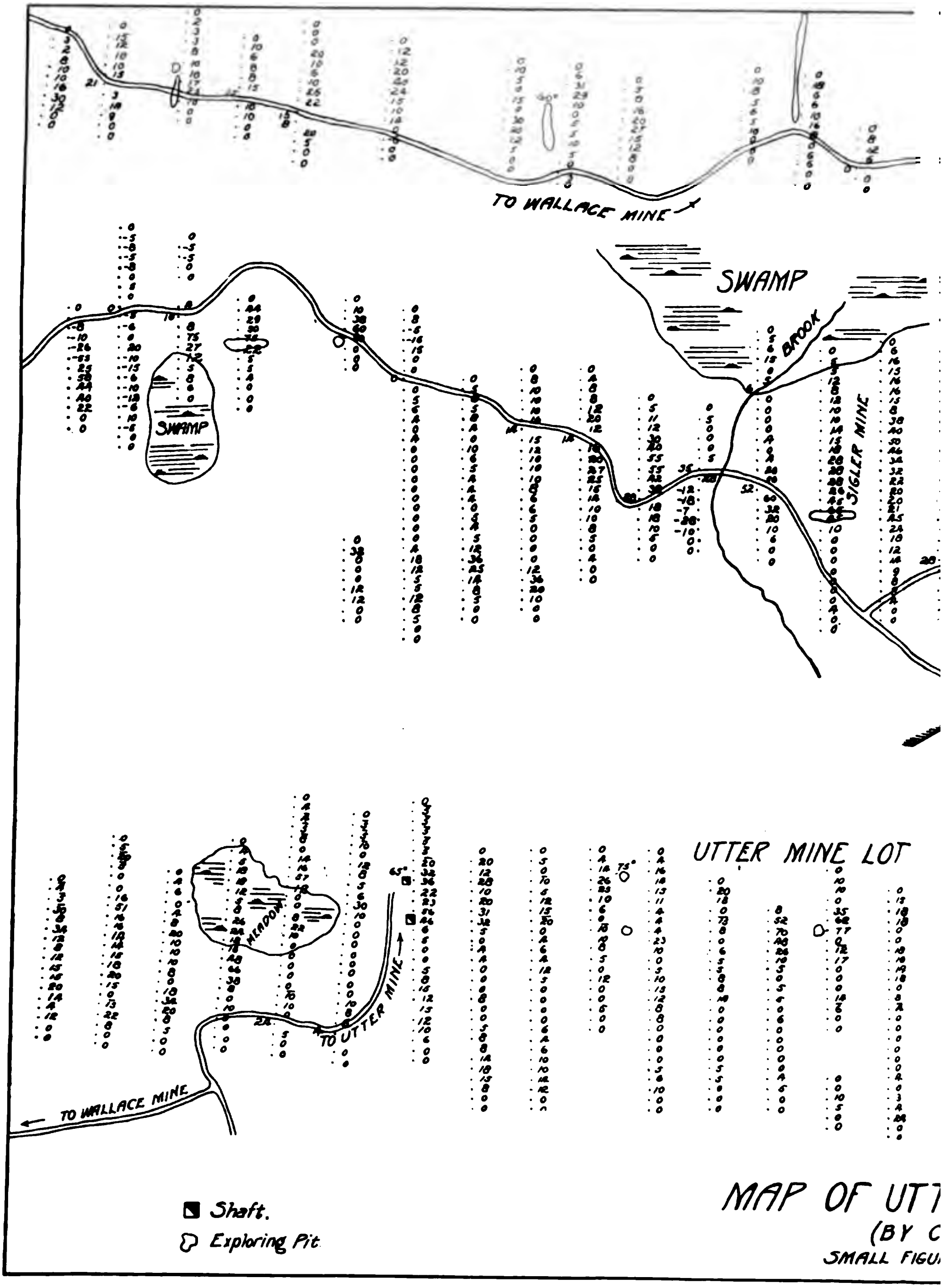
(181) The Wallace Mine.

The Wallace mine was worked in 1874 and 1,500 tons of lean ore were shipped. The deepest shaft was down 35 feet at this time. Mr. Utter, who worked in the mine when it was being operated, declares that it is now 200 feet deep. If this is the case the mine must have been again opened subsequent to 1874.

References: N. J. 1879, p. 82; 1883, p. 140.

(182) The Utter Mine.

The Utter mine is the name here applied to a series of test pits and shallow shafts situated in a northeast line along the crest of a small hill about a mile northwest of Uttertown. They are in the same zone of attraction as the Rutherford mines and about one and a half miles further northeast.


TO WALLACE MINE
SWAMP
BROOK
SIGLER MINE
SWAMP
UTTER MINE LOT
MEADOW
TO UTTER MINE
TO WALLACE MINE
Shaft.
Exploring Pit
MAP OF UTT
(BY C
SMALL FIGU

The openings were not much more than explorations, although from some of them considerable lean ore was raised. They seem to be near, if not upon, the line of attraction running through the Wallace mine. None of the holes are deep. It is said that the pits disclosed the existence of two veins. Of these the eastern one contained much pyrite. The western one was probably a magnetitic pegmatite.

Reference: N. J. 1883, p. 140.

(183) The Carey Mine.

The Carey mine, in West Milford Township, Passaic County, was on the south side of the road leaving the main road from Uttertown to Warwick, about 2.5 miles north of Uttertown.

The mine was opened some years before 1886. The ore body is said to have been 7 feet thick. The ore contained much pyroxene and epidote. It was mined through a shaft 27 feet deep and from an open cut about 35 feet long. It is not known how much ore was raised, but from the appearance of the dump-heap it seems probable that very little, if any, was shipped.

Reference: N. J. 1886, p. 138.

(184) Squier's Mine.

The Centennial, or Squier's mine, was in the woods on the east side of the Warwick-Greenwood Lake road, near the State line, in West Milford Township, Passaic County.

The mine was first opened in 1875 on a line of attraction 2,400 feet long striking north 38° 30′ east. Eight pits and cross-cuts showed the ore to be 12 feet wide in general, and at one place at least 38 feet in width. At the end of a drift stripping revealed the presence of five veins, each about 5 feet wide and all dipping 80° southeast. During the year 1,500 tons were raised. The mine was worked until 1879, when it was closed. It appears to have been operated a short time also in 1880. The total yield of the mine is estimated at 2,200 tons.

The ore contained varying proportions of feldspar, quartz, epidote and pyrite. Analyses of the surface ore (1) and material from the deeper openings (2) gave:

	Fe	*P*	*S*	*Ti*	*Mn*	*Authority*
1—	48.16	.14	3.02	.0	.0	N. J. 1876, p. 54
2—	55.39	.067	1.74	.0	.0	N. J. 1876, p. 54

References: N. J. 1876, pp. 53-54; 1879, p. 82; 1880, p. 116; 10th Census, p. 154.

THE VAN SYCKLE MINE BELT.

The Van Syckle mine belt runs along the southeast side of Musconetcong and Schooleys mountains.

The belt begins on the south side of Musconetcong Mountain, near the Delaware River, and follows the southeast side of this mountain and Schooleys Mountain as far north as German Valley. It then turns more northerly and extends along Mount Olive at a distance of about 1 mile from the southeast side, crossing the Delaware, Lackawanna and Western railroad at Shippenport and terminating a few miles beyond at Mount Arlington. on Lake Hopatcong.

No mines of importance are situated along the belt. The Van Syckle mine and the Naughright mine are the best known, both being remarkable for the large quantity of titanium in their ore. Indeed, the same feature is also noticeable in the ores of the few other mines that have been sampled, so that it is possible that the belt is characterized by deposits in which titanium is an important constituent. Unfortunately analyses are too few to warrant drawing from them a generalization to this effect, but all point to the same conclusions.

(185) The Bloom Farm Mine.

The Bloom farm or Little York mine was about 1 mile west[1] of Little York, in Holland Township, Hunterdon County, at the foot of Musconetcong Mountain.

[1] Another report places it one mile north of Little York, on the farm occupied by P. C. Bloom in 1873. If this is the correct location, as it seems to be, the openings were in the Hurd mine belt.

About 150 tons of ore were raised in 1873 and 1874, but whether it was shipped or not is not known. An analysis of ore presumably from this mine showed it to be lean, but of Bessemer grade, except for the large quantity of titanium in it.

Ins.	*Fe*	TiO_2	*P*	*S*	*Authority*
49.7	37.5	4.7	tr	tr	N. J. 1875, p. 35

Nothing further was ever done here so far as known.

References: N. J. 1874, p. 26; 1875, p. 35; 1879, p. 63.

(186) The Duckworth Farm Explorations.

The Duckworth farm explorations were 1 mile west of Little York, in Holland Township, Hunterdon County, near the base of Musconetcong Mountain.

The first opening was made about the time of the Revolution, but was soon afterward abandoned. In about 1877 the locality was re-explored by two shafts, 50 feet and 25 feet deep, both of which encountered thin veins of ore. Explorations continued intermittently through 1879 but nothing further of importance was discovered.

The ore was found to contain:

$Fe = 64.32\%$; $P = 0.0039\%$; $Ins. = 9.92\%$. Authority: N. J. 1879, p. 63.

References: N. J. 1879, p. 63.

(187) The Martin Mine.

The Martin mine was 2.5 miles southwest of Pattenburg, in Alexandria Township, Hunterdon County, on the south slope of Musconetcong Mountain.

The ore was mixed with hornblende and was therefore quite lean. An analysis made in 1878 gave:

$Fe = 49.25$; $Mn = 0$; $P = .25$; $TiO_2 = 1.00$. Authority: N. J. 1878, p. 100.

The mine was never worked.

References: N. J. 1878, p. 100; 1879, p. 63.

(188) The Case Mine.

The Case mine was in Bethlehem Township, Hunterdon County, about a mile southwest of Pattenburg.

The place was opened in December, 1879, and worked three months. About 25 tons of ore were obtained, when the operations were suspended because of lack of machinery.

References: N. J. 1880, pp. 110 and 123; 10th Census, p. 162.

(189) Van Syckle's Mine.

The Van Syckle or Church mine is an opening near the forks of the road, about 1 mile northwest of Van Syckles, in Union Township, Hunterdon County. The mine is just across the town line in Bethlehem Township. The ore is notable for containing a very large quantity of titanium and some vanadium.

The mine is a very old one, the original opening having been made during the later years of the 18th century. It was abandoned and lay idle for nearly 100 years and was then reopened in 1864. By 1868 the new opening had reached a depth of 60 feet and a length of 20 feet. Shortly after this date the mine was closed, but it was again opened in 1871, and it continued in operation until 1875, when it was permanently abandoned. Its total yield during the last period of its activity was 4,390 tons of ore.

The main deposit was 11 feet wide. In this the ore was interlayered with streaks of chlorite rock. A second deposit northwest of this one was 7 feet wide, but the ore was very lean. Lines of magnetic attraction were observed in the fields to the northeast of the mine opening, but no explorations were made to ascertain their significance.

An analysis of the ore made by Britton in 1871 and another made in 1873 yielded:

Fe_3O_4	Al_2O_3	MnO	CaO	MgO	SiO_2	TiO_2	P_2O_5
69.40	4.36	.19	.46	2.52	7.92	10.52	.02
69.34	9.29	.00	.39	3.35	5.40	11.60	tr

S	H_2O	Org.	Total	Authority
1.46	.49	2.69	= 100.03	T. A. I. M. E., Vol. 21, p. 275.
1.21			= 100.58	N. J. 1873, p. 55

Ten analyses of material taken from different portions of the vein showed an average of 12 per cent. of TiO_2, with extremes of 9.82 per cent. and 15.05 per cent. It is also reported by Mr. Raymond that Mr. Walz discovered in three samples of the ore the following percentages of vanadic acid: 0.38, 0.31 and 0.13 per cent.

References: N. J. 1868, p. 616; 1873, pp. 55-56; 1879, p. 65; 10th Census, p. 162; Trans. Amer. Inst. Min. Engineers, Vol. 21, p. 275; N. J. 1899, p. 165.

(190) Banghart's Mine.

The Banghart mine never amounted to more than an exploration. It was situated in Lebanon Township, Hunterdon County, about 1.25 miles northeast of Glen Gardner.

Three openings were made shortly before 1868, but they disclosed only a very lean ore, containing considerable pyrite and chalcopyrite. No workable deposit was found, and the mine was therefore abandoned. Explorations were evidently renewed in 1879. A shaft 35 feet deep was sunk and a vein of ore was found 3 feet wide. The mine was thereupon abandoned.

References: N. J. 1868, p. 617; 1873, p. 56; 1879, p. 66.

(191) The Alvah Gray Mine.

The Alvah Gray, or Alvan Gray, or Alvey Gray, or Sand Flats mine, or the Fritts farm mine, was about three-fourths of a mile southwest of Woodglen, in Lebanon Township, Hunterdon County.

The mine was opened in 1873, and a wide vein of lean ore was found. It was worked for a short time and about 400 tons were raised. The mine was then closed, but was reopened in 1879, and about 3,500 tons were mined before it was again closed, in the following year.

The ore at the surface was comparatively free from sulphur. It became more sulphurous with increasing depth until finally the mine had to be closed. Its metallic content averaged about 52 per cent.

There was thought to be additional ore in the foot-wall side of the vein, but it was not searched for. The total yield of the mine is estimated at 8,400 tons.

References: N. J. 1873, p. 56; 1879, p. 66; 1880, pp. 111 and 124; 10th Census p. 162.

The Fritts Farm Mine.

The Fritts farm mine was a short distance northwest of Woodglen, in Lebanon Township, Hunterdon County, but its exact location is not known. It may have been a part of the series of explorations later known as the Alvah Gray mine.

A shaft was sunk in 1873 on a wide vein of quartzose granular ore.

Reference: N. J. 1873, p. 56.

The Terraberry Farm Exploration.

The Terraberry farm explorations were about three-fourths of a mile south of Woodglen, in Lebanon Township. Hunterdon County.

A few openings made some time in the 70's discovered a lean ore mixed with hornblende and mica.

Reference: N. J. 1879, p. 66.

The White Hall Mine.

The White Hall mine was east of Woodglen in Lebanon Township, Hunterdon County.

A vein of lean ore was opened between 1870 and 1873. It was regarded as the northeast extension of the Banghart mine vein, and was not further explored.

There is some confusion in the description of the explorations near Woodglen, so that it is now impossible to be sure that several of them have not been referred to under the same name, and on the other hand, it is not certain that different names are not used by different writers for the same exploration. In any event

it is certain that considerable bodies of lean ore exist in the neighborhood of the village.

References: N. J. 1873, p. 56; 1879, p. 66.

(192) The Lake Farm Explorations.

The Lake farm explorations were east of Schooleys Mountain, in Washington Township, Morris County.

A shaft 30 feet deep was sunk in 1875 and a small quantity of ore was taken out, some of it very rich, but much very lean. The place was soon closed down, but it was reopened in 1879, with what result is not known.

The location of this exploration is not given in the only reference to it that has been seen. It was probably identical with the Lake mine of the topographic map, which is shown one-half a mile southwest of the Naughright mine, on the north side of the road, between Naughright and Drakestown.

Reference: N. J. 1879, p. 69.

(193) The Naughright Mine.

The Naughright mine was on the east side of Schooleys Mountain, about 1 mile north of Naughright, in Washington Township, Morris County.

The mine was opened in 1870 and worked about a year through two shafts, of which the southeast one was 140 feet deep, measured on the slope. This penetrated a vein from 20 inches to 4 feet thick, of a coarsely crystalline ore mixed with some rock and pyrite. An unusual feature of the deposit is the fact that it is cut off at its northeast end by a large trap dike that intercepts it at an oblique angle. The second shaft, 30 feet deep, was situated about 100 yards west-northwest of the first one. The vein here was 8 feet wide, and here also the deposit was suddenly cut off by rock. About 200 tons of ore had been raised when the mine was closed.

It was reopened a few years later and operated until the early part of 1879, when it was again closed for a few months. It was

again reopened in the latter part of this year, and a little exploring was done. This resulted in the finding of a new vein 3.5 feet wide. No mining was undertaken. The property remained untouched until 1883, when there was a little more exploring done, but without definite results. Since this time, so far as is known, the place has remained deserted.

The ore, like that of many of the other mines in this belt, was remarkable for the large quantity of titanium shown by the analyses. Two samples, reported to be averages, gave:

	Fe_3O_4	CaO	MgO	S	P_2O_5	TiO_2	*Insol.*	*Total.*	*Authority*
I	89.39			.27	.16	7.50	2.20	= 99.52	N. J. 1878, p. 100
II	87.78	2.70	.91	.04	2.56	6.40	2.40	= 97.79	N. J. 1878, p. 100

I.—Compact lustrous blue ore from vein 20 feet wide.
II.—Gray ore, containing apatite, from vein 4.5 feet wide.

References: N. J. 1873, pp. 58–59; 1878, pp. 99–100; 1879, p. 69; 1880, p. 111; 1883, p. 126.

(194) The Wm. Sharp Mine.

The Wm. Sharp mine was a short distance northwest of the Naughright mine, near the road from Naughright to Drakestown, in Washington Township, Morris County.

In 1870 a shaft 25 feet deep was sunk in a deposit of mixed rich and lean ore dipping southeast. It is not known how extensively the mine was worked. It was idle in 1879, but was prospected again in 1880, and 30 tons of ore were obtained.

References: N. J. 1873, p. 59; 1879, p. 69; 1880, p. 111.

(195) The Rarick Farm Explorations.

The Rarick farm exploration was at a point just north of the Sharp mine, in Washington Township, Morris County.

The place was first explored in about 1870, uncovering a magnetiferous rock. No distinct ore deposit was found. The place was idle in 1879 and has not been worked since.

References: N. J. 1873, p. 59; 1879, p. 69.

(196) Mariot's Mine.

Mariot's mine was a short distance east of Shippenport, in Roxbury Township, Morris County.

This was probably merely a small exploration. Nothing is known of its history. All that can be seen now is a small pile of rock at the mouth of a shallow pit.

Reference: N. J. 1883, p. 128.

(197) The Gove Mine.

The Gove mine was near Mountain Pond, 1.5 miles north of Drakesville, and about one-half a mile north of the Mount Arlington quarries, in Roxbury Township, Morris County.

The mine was first opened in 1874 and worked for a short time and then closed. It was reopened in 1879 and operated until 1881. During this period two shafts were sunk to a depth of 400 feet and a great quantity of rock was raised.

The ore body was 7 feet wide when developed. The ore was rich, but it contained a great deal of pyrite in streaks.

The yield of the mine to June, 1880, was estimated at 11,200 tons.

References: N. J. 1879, p. 71; 1880, p. 112; 10th Census, p. 161; 1883, p. 128.

(198) The Silver Spring Mine.

The Silver Spring mine was on the top of a knoll, about 1 mile south of Mount Arlington, on the west side of the road from this place to Mt. Arlington station, on the Delaware, Lackawanna and Western Railroad.

The place was explored about 1882 and opened shortly afterward. A considerable quantity of a sulphurous ore was raised, and a good deal of work was done about the shafts. Operations did not continue long, however, and so far as is known none of the ore was shipped. The country rock in the neighborhood is a garnetiferous gneiss interbanded with Byram gneiss. The ore is a richly magnetiferous Pochuck gneiss.

Reference: N. J. 1883, p. 128.

(199) *The Lurk Mine.*

The Lurk mine was one-half mile southeast of Mt. Arlington, in Roxbury Township, Morris County. The exact location of the openings has not been learned. They may be nearer the Van Syckle than the High Ledge belt of mines.

The mine was discovered in 1904 by a shaft 18 feet deep and drifts of 100 feet. The deposit is 6 feet wide, but the ore contains streaks of rock. About 400 tons were raised. A selected sample was found to contain 66.534 Fe and .099 P. Four carloads sent to the Wharton Furnace yielded respectively, 64.482 per cent., 58.405 per cent., 56.717 per cent. and 54.016 per cent. in iron. Operations were suspended at the beginning of winter, and so far as known were never resumed.

References: N. J. 1904, pp. 295–296.

(200) *The Cone Mine.*

The Cone mine was a shallow pit about a mile northwest of Upper Longwood, in Jefferson Township, Morris County.

Nothing has been learned about the place. From the appearance of the pit, however, it is surmised that it never yielded any ore.

THE HIGH LEDGE BELT.

The High Ledge belt of mines skirts the southeast side of Mount Olive, beginning at the south near Bartley and ending at the north near Berkshire Valley. It crosses the Delaware. Lackawanna and Western railroad just west of Mount Arlington station.

The mine openings along this line are unimportant. The only one that ever developed into a shipping proposition was the High Ledge mine near Drakesville. Some of the others shipped ore during a single season, but merely as an experiment.

(201) *The Hopler Mine.*

The Bartleyville or Hopler mine was in Washington Township, Morris County, on the brow of the hill, 1.25 miles west of

Bartley. It was at the southwest end of the southern Mt. Olive magnetic belt (see page 324), and is practically the only opening made in it. There were several pits a mile or so further northeast, but they never developed ore and so were abandoned before they reached any great depth. The attraction farther north is not as strong as it is in the vicinity of the Hopler mine, and it is probably for this reason that it was not more systematically explored. The great difference in the number of pits dug on this belt as compared with the number excavated on the northern belt is accounted for in the same manner, *i. e.*, by the comparatively light attraction as compared with that in the northern belt.

Ore was found here before 1868, but the mine at that time was little more than an exploration. A strong magnetic attraction was, however, observed over a large area. In 1879 the place was again explored and some good ore was found, the remains of six pits giving evidence that the place was once thought promising. In 1881 the property was leased by the Thomas Iron Company and about 167 tons of ore were mined at a royalty of fifty cents per ton. The lease was then surrendered.

References: N. J. 1868, p. 597; 1873, p. 59; 1879, p. 69.

(202) The High Ledge Mine.

The High Ledge mine was on the slope of Schooleys Mountain, about one-half a mile west of Ledgewood, in Roxbury Township, Morris County.

Two shafts were sunk in 1880. Of these the southeast one was put down 55 feet into a shoot of ore from 6 to 20 feet wide pitching northeast. The ore was reported to contain about 65 per cent of iron and from 1 per cent. to 3 per cent. of sulphur. The second shaft was 200 yards further northwest. It was sunk 30 feet into a deposit 6 feet wide.

The mine was worked for a few months and was then closed, after having yielded 1,120 tons of ore. It was reopened in 1883 and worked for a few months and was again closed.

An analysis of the ore showed it to run between 58 per cent. and 60 per cent. metallic iron.

References: N. J. 1880, pp. 112 and 124; 10th Census, p. 161; 1883, p. 127; 1899, p. 162.

The King Mine.

The King mine was in Roxbury Township, Morris County, on the hill about a mile northwest of Ledgewood, and about three-quarters of a mile west of the High Ledge mine.

The mine was opened in 1879, but it had been explored several years earlier. It was worked a few months and closed in the early part of 1880, during which time it produced 280 tons of ore. At the time of closing the shaft was down 50 feet in an ore shoot 6 to 12 feet wide. The ore contained no sulphur and only a little phosphorus, but a considerable quantity of white feldspar. The mine was opened again in 1905 and a small quantity of ore was taken out of it, when it was again closed.

References: N. J. 1879, p. 71; 1880, pp. 112 and 125; 10th Census, p. 161; 1883, p. 127; 1905, p. 320.

(203) The Burt Mine.

The Burt mine was near the base of the hill one-half a mile west of Mt. Arlington station, in Roxbury Township, Morris County.

The location is an old one. It was opened many years ago, but its early history is now unknown. It was reopened in 1882 and operated during the succeeding year.

Within a quarter of a mile there were seven shafts in the vein, which outcropped on the hill slope 70 feet from its base and varied in width from 6 feet to 24 feet. The deepest shaft was down 80 feet, and was connected with a shaft 100 feet to the northeast by underground drifts. In the main shaft the dip was to the west-northwest, but in all the others it was, as usual, to the southeast.

The ore was lean and sulphurous. About 400 tons were shipped, and much more had been raised when work was suspended.

An analysis of a roasted magnetite from near Mt. Arlington, which may have come from the Burt mine, yielded:

$Fe = 43.18$; $SiO_2 = 21.43$; $P = .213$; $S = .783$. Authority: N. J. 1899, p. 170.

References: N. J. 1883, p. 128; 1889, p. 170.

(204) The Davenport Mine.

The Davenport mine consisted of a shaft and several small openings in Jefferson Township, Morris County, 1 mile west of Berkshire Valley, between the road leading to Nolans Point and the Lake Hopatcong branch of the Central Railroad of New Jersey.

The mine was opened in 1868 by a shaft and slope 40 feet deep. It was worked 40 feet in a vein that was reported to be 6 feet wide, half of which was rock. The deposit dipped 50° to 60° northwest.

The mine was never operated.

References: N. J. 1868, pp. 602–603; 1873, p. 66; 1879, p. 71.

THE HIGH BRIDGE BELT.

The High Bridge belt of mines extends from High Bridge, in Hunterdon County, to Echo Lake, in Passaic County. Beyond this point to the State line no explorations have been made.

The principal mines in the belt are grouped around High Bridge, at its southern end, and around Wahrton in its middle portion. A number of the mines have been important shippers, but the ore as a whole was rather sulphurous. Where the belt skirts the east base of Copperas Mountain the sulphur content is very high, but the phosphorus is so low that the ore is below the Bessemer limit.

(205) The High Bridge Mines.

The High Bridge or Taylor mines were just north of High Bridge, in High Bridge Township, Hunterdon County, along the road leading to Readingsburg. Together with a few openings on the hill east of this village they constitute a short line of mines and explorations, about one-fourth of a mile east of the main line, which passes through the Kean mines and continues northeast all the way to the State line.

Some of the many openings of the High Bridge mines are reported to have been made as early as 1720, and to have yielded

an abundance of good ore. By 1868 the vein had been worked for a distance of nearly three-fourths of a mile, in some places to a depth of 200 feet. In the following eleven years the vein was followed to the southwest, and a large quantity of ore was removed from it. In 1879 it was abandoned. The main portion of the old (northeast) mine was also closed during this year, but 2,000 tons were raised during the latter part of 1879 and the early portion of 1880 from above the water level in an opening known as the Taylor mine at the east end of the vein. In 1886 a new shaft was sunk, which disclosed at a depth of 30 feet about 4 feet of ore and a number of small veins. The dip of these deposits was 72° southeast, and their pitch 40°–47° northeast. The place was abandoned in 1889.

The vein varied in thickness from 2.5 feet to 18 feet, and dipped southeast at 65°. Near its northeast end a fault displaced the ore body approximately 20 feet. On the hanging side was a thick layer of very pyritiferous ore that was taken out and thrown on the dump. Many years later the pile was examined and the ore upon it was found to be sufficiently pure to be utilized in the forge. It was practically free from sulphur.

Later observations showed that the ore was in the form of a series of shoots that lay slightly oblique to the course of the vein, which was nearly northeast. All the shoots pitched toward the northeast, those to the north declining at a greater angle (in some cases 60°) than those further south. In the southwest portion of the vein there were four parallel shoots separated by only a few feet of rock. One of these was 55 feet thick, and in some places others measured 100 feet. With increasing depth their thickness diminished until at the bottom of the shafts, when work ceased, their breadth was only 1 or 2 feet. It is noteworthy that none of them pinched out completely. The thinning of the deposits is ascribed to the flattening of the dip of the foot-wall. The dip of the vein in which the shoots lay was steep to the southeast, and in some places was vertical.

Trial shafts put down at the north foot of the hill, on the south slope of which are the principal openings, found no ore.

Only a few analyses of the ore of this mine have been published. Two, made in 1868, are as follows:

Fe_3O_4	*Insol.*	*S*	P_2O_5	*Iron*	*Authority*
75.1	15.4	.0	tr	54.4	N. J. 1868, p. 617–618
91.9	5.4	.0	.3	66.6	N. J. 1868, p. 617–618

A sample of a few tons taken from the Taylor pit gave:

$Fe = 55.15$; $S = 5.172$; $P = .609$. Authority: 10th Census, p. 164.

Some rich samples picked from the old dump in 1895 gave:

$Fe = 61.07$; $SiO_2 = 7.81$; $P = 0.405$; $S = 0.853$; $TiO_2 = 9.40$. B. F. Fackenthal, Jr.

Between 1864 and 1889 the mine was operated by the Thomas Iron Company, during which period there were shipped 69,180 tons of ore. Considerable ore had been recovered previous to its purchase in 1864, but the aggregate yield is not known.

References: N. J. 1868, pp. 617–618; 1873, p. 29; 1879, pp. 43–44; 1880, p. 102; 10th Census, p. 164; 1886, p. 143.

(206) *The Kean Mines.*

The Silverthorn, or Kane, or Kean, explorations were on the southeast slope of a hill 1 mile north of High Bridge, in High Bridge Township, Hunterdon County.

The locality was tested about 1875 by several shallow holes, in one of which a vein was encountered several feet wide, dipping southeast. The ore contained pyrite and hornblende. The place was abandoned soon after work was begun, but was reopened in 1880, and about 200 tons of ore were produced. It was worked again in 1881, producing 1,600 tons of ore, but was again closed before 1884.

The ore appears to have been in large irregularly-shaped deposits, constituting a belt 100 feet wide, in which ore and rock are interspersed. The surface ore was red and free from sulphur, below this it was blue, lean and very sulphurous, and beneath this was compact and quite free from sulphur. The deepest openings had penetrated only 80 feet when the mine was closed and abandoned.

From the number of openings observed it is clear that the place was pretty thoroughly explored.

References: N. J. 1879, pp. 44–45; 1880, p. 102; 10th Census, p. 164; 1881, p. 37; 1884, p. 74.

No other openings occur in this line for a distance of 25 miles, except one small exploration pit on the hill east of Readingsburg, another on the west side of Raritan River about 1.5 miles further north (the Burd mine), and a third 3 miles northeast of Califon.

At Ferro Mont, east of Vanatta Station, however, mine openings become plentiful, and from this point to a short distance beyond Wharton, a distance of 4 miles, the vein has been exposed almost continuously (Plate VIII), and in it have been developed a number of very important mines.

(207) The Black Hills Mine.

The Black Hills Mine is in Randolph Township, Morris County, on the hill south of the Dickerson mine.

Several pits were dug at different times, but none of them developed into important mines. The place was first worked in 1879 and 1880, and was then abandoned. In the census year 1879-1880 it produced 2,195 tons of ore. In 1899 work was resumed. The pits were unwatered and preparations were made for active mining. Mining was begun in 1900, and 500 tons of ore were raised, when operations again ceased after the deposit had been opened for a distance of 225 feet and to a depth of 100 feet. Later (in 1905) one of the old shafts to the south was cleaned out and reopened, but this also was soon abandoned. Its ore consists largely of a Losee gneiss interlayered with thin veins of magnetite.

The various developments showed the presence of four small veins of ore that is rich in iron and low in phosphorus, but the ore is so intimately intermixed with quartz that the metallic content of the material raised was only 43 per cent. to 45 per cent.

References: N. J. 1879, p. 51; 1880, p. 105; 10th Census, p. 169; 1890, p. 98; 1899, p. 161; 1900, pp. 205–206.

(208) The Dickerson Mine.

The Dickerson mine, in Randolph Township, Morris County, is one of the oldest and most celebrated in the State. Its history has been written by F. A. Canfield, and the account is printed in the State Geologist's Annual Report for 1891.

The mine is about 3 miles southwest of Dover, one-fourth of a mile west of the Evers mine, and about the same distance northeast of the Black Hills mine. From Mr. Canfield's account we glean the following facts: (An. Rep. State Geol. N. J. 1891, p. 251-253):

"The tract of land on which the Dickerson mine is opened was taken up as a mining tract in 1713, by John Reading, surveyor, for Joseph Kirkbride, who left it to his three sons, Joseph, Jr., Mahlon and John, members of the Friends' Society of Bucks county, Pennsylvania. Jonathan Dickerson, father of Governor Mahlon Dickerson, began to buy interests in the property about 1780. His son Mahlon succeeded to his father's interests in 1807, and added to them by purchase until he had acquired all. At his death, in 1853, the property descended to his nephews and nieces, who formed the original stockholders of the Dickerson-Suckasunny Mining Company, the present owner. The mine has been in the possession of the family and its representatives, from whom it was named, for over a century.

"Before the mine came into the possession of Mahlon Dickerson it was worked under a system of forge-rights, whereby certain forge-owners had the right to get the ore needed by them at this mine. The ore was a favorite among forgemen because of the ease with which it was reduced, and because of the fine quality of the iron made from it.

"From 1826 to 1830 one hundred forge fires were run with his ore. It was carted as far as High Bridge in a southern direction, and northward as far as Hamburg, in Sussex County. The forges in Longwood valley, Newfoundland, Stockholm, Sparta, Hurdtown, Chester, Mendham, Logansville, Bartley, Whippany, Morris Plains, Rockaway, Stanhope (and it is said that some in Monmouth County) drew their supply from this mine. As money was scarce, the ore was often paid for with bar iron, which was bent and carried on horseback over trails and bad roads. After the Morris canal was opened to Easton, Pennsylvania, the ore was sent to the Lehigh region, where it was reduced in furnaces using anthracite.

"Governor Dickerson worked the mine in a small way, regulating the production by the demand, and probably mined 2,000 tons of ore a year. The mine was worked more actively after 1854 until the depression in the iron business, from 1857 to 1860, when the mine was closed, the company having from 25,000 to 30,000 tons of ore in stock which could not be sold at that time. The mine was closed from 1860 to 1862, when the Allentown Iron Company made a lease of the old mine for fifteen years at seventy-five cents a ton royalty. It was worked by this company until 1877. In 1871 the firm of E. Canfield & Co. leased the remainder of the property for six years at a royalty of one dollar per ton; and in 1877 Mr. Ario Pardee (who was in the firm of E. Canfield & Co.) took the entire property and worked it actively until November 16, 1891. In 1883, owing to the great expense of securing the old parts of the mine and the difficulty in raising the ore to the surface up the long 1,300-foot slope, the owners decided to sink a vertical shaft, which at 550 feet cut the 'side vein' and at 750 feet the 'big vein.' The depth of the big mine is about 1,300 feet.

"About 1889 an offset was encountered in both veins which threw the northerly end of the vein about 35 feet east. The ore in the vein 'inside' the offset seemed to be totally different in character from that in the main part of the vein, and being very stringy and rocky, and getting worse and worse, caused the lessees to surrender the lease and close the mine. There is little doubt that this offset had a vertical as well as a horizontal 'throw' and that the ore found was the same as that which was left in the so-called 'cap-rock' higher up.

"The owners have tested the ground with many diamond drill holes, which have proved that the ore deposit is not exhausted, although no large bodies of ore were found. The further working could be carried on if it were not for the depressed condition of the iron market. At the present prices for iron the old mine may be regarded as economically exhausted, that is, it will not pay to work it.

"It is estimated that about 1,000,000 tons of ore have been taken from the mine. The largest output for any year was 48,000 tons."

The main ore body was a large irregularly-shaped lens embedded in gneiss, its longest diameter coinciding both in strike and dip with these features of the gneiss. The lens thinned out at its borders to acute edges, which in some cases were split by wedge-shaped masses of rock that sometimes penetrated to a considerable distance into the ore body. Usually the rock and ore were sharply separated from one another. In its thinner portions the ore was often crossed by joint planes that were approximately perpendicular to its walls. This structure was best developed where the ore was purest. This deposit was known as the "Big Mine" shoot. In general, it dipped 60° southeast and pitched northeast 35° to 48°.

At the southeast end of the mine, as developed in 1883, was the "Side Vein," and at the southwest end was the "Cow-Belly vein." The strikes of the veins varied somewhat. That of the "Cow Belly" was more nearly east-west than the others. The "Side Vein" was first found at a depth of about 250 feet, running into the hanging wall of the "Big Mine." It was always in the hanging wall and always a little to the northeast of the "Big Mine" at the same level, and about 100 feet from it. The northeast end of the "Side Vein" had a peculiar habit of rolling over into the footwall, so that what was the foot wall became the hanging wall. The ore was very rich and at times the vein was large. The rare mineral isopyre occurred in this vein. The "Cow Belly" was also irregular in shape. Its name was due to its great width in places.

Its pitch was 35°–48° northeast and its dip 55°–60° degrees southeast.

As the developments in the mine proceeded it was learned that the "Big Vein" deposit varied greatly in dimensions. At its widest part it was 40 feet broad and 78 feet long. Its horizontal section at the bottom of the shaft was 400 feet long and 18 feet wide. The great length was due to the merging of the "Big Mine" deposit with the "Cow-Belly" deposit.

The pinches seemed in all cases to be due to the inequalities of the foot wall. With increasing depth below 1,200 feet the ore body gradually diminished in size and the quantity of rock intermingled with the ore constantly increased. At the bottom of the deposit the ore was interlayered with rock, but in the pinches between the shoots the ore was pure and had a distinct prismatic parting. In the hanging wall the transition from ore to rock was sudden, though there was no physical break between the two. There were many pinches in the ore body and numerous small faults with throws to the right. In the upper portion of the workings two distinct varieties of ore were observed. One was a coarse-granular variety and the other a fine-crystalline one, the two being separated by a horse of rock.

The "Cow-Belly" mine was closed in 1883, but the shoots of the "Big Vein" and the "Side Vein" were in operation throughout the year. The deposit was large, but its ore was much streaked with rock. The "Side Vein" was only 8 feet wide, but its ore was the richest in the mine.

At the depth of the workings in 1884 it was found that the "Big Vein" and the "Cow-Belly" deposit were only 25 feet apart, whereas at less depths they were distant 125 feet. About 1890 the two deposits merged, forming the ore body about 400 feet long referred to above.

In March, 1885, work was suspended in the "Big Vein" because of caves. Most of the work during this year was concentrated on the sinking of a new shaft on the "Big Vein." In the next few years all the ore was removed from the shoots then known, and the fault referred to by Mr. Canfield was encountered. Searches for new shoots being unsuccessful, the mine was abandoned in 1891.

In 1905, however, searches for new ore bodies were resumed, and a small shoot, lying in the hanging wall of the "Side Vein" and parallel with it, was opened up by a new shaft east of the older ones. A small quantity of ore was removed in that year. Mining was continued through this shaft until January, 1908, at the rate of about 8,000 tons per annum.

All the ore of the mine was the granular variety known as "shot ore." The purest ore, as has been stated, was in the "Side Vein." The leanest and that containing the most phosphorus was in the "Cow-Belly" deposit. In this the phosphorus content sometimes reached as high as 2 per cent.

Analyses of the ore made in 1868 indicate that the material being raised in that year from the "Big Vein" was rich in iron and high in phosphorus.

	Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Authority
Average sample, ..	96.0	3.7	0.0	.6	N. J. 1868, p. 574
Good ore, ...	95.2	3.2	0.0	.3	N. J. 1868, p. 574

Samples taken from the "Big" or "Main Vein" and the "Side Vein" at a later date gave:

	Fe	P	Authority
Sink in main vein, ...	61.62	1.186	10th Census, p. 169
Near botom of main vein, ...	65.17	0.282	10th Census, p. 169
Side vein, ...	63.63	0.178	10th Census, p. 169

References: N. J. 1855, pp. 215–220; 1868, pp. 570–574; 1873, p. 43; 1879, pp. 51–52; 1880, pp. 105–106; 10th Census, p. 169; 1882, p. 70; 1883, pp. 100–103; 1884, p. 83; 1885, p. 99; 1886, p. 140; 1890, pp. 59–60; 1891, pp. 242 and 251–253; 1905, p. 320.

(209) The Canfield Mine.

The Canfield mine was at Ferro Mont, in Randolph Township, Morris County, about one-quarter of a mile north of the Dickerson mine, on the road between Ferro Mont and Kenvil, apparently on a vein a little west of the vein at the Dickerson mine.

The mine was first explored in 1870 on a vein which in places was 20 feet wide, but in which was interlaminated considerable rock. The ore contained a very little phosphorus. It was cut by joints running from wall to wall of the ore body, separating it into columns.

About 200 feet west of this was another vein, 4 to 6 feet wide and dipping 40° southeast. This also contained much rock. The ore body was penetrated by a shaft from which considerable drifting was done.

In 1873 over 6,000 tons of ore were raised from the two veins. Shortly afterward the mine was abandoned.

References: N. J. 1873, p. 43; 1879, p. 52.

(*210–211*) *The Baker Mines.*

The Baker mines covered a large area on Mine Hill, in Randolph Township, Morris County, 3 miles west of Dover, on the road from that city to Kenvil. In all there were a dozen openings besides those operated under the same name one-half mile further east. The western Baker mines have been worked under several names, some of which have lost their significance and cannot now be assigned to any definite openings. The two groups of shafts that are recognizable are the "Baker mine at the base of the hill" and the "Baker mine No. 1."

(*210*) The "Baker mine at the base of the hill" (the northwest Baker of the Report of 1868) was on both sides of the road between Dover and Kenvil, on the west slope of the hill overlooking Kenvil, probably on the same vein as the Canfield mine.

The mine was not worked much prior to 1868, at which time a depth of 45 feet only had been reached. From this date, however, to 1883 it was kept in operation practically continuously. In this year, when a depth of 300 feet had been attained, mining ceased because of the leanness of the ore. A little exploration was undertaken 3 years later, but no ore was raised. Other than this no work has been done since the mine suspended operations in 1883.

The Baker mine was thought to be on the same vein as the Corwin mine, but this is not proven. The ore body had a thickness of 7 or 8 feet at its southwest end and 4 feet at its northeast end. The percentage of iron in it ranged between 35 per cent. and 40 per cent. Phosphorus was low and quartz high. The ore is reported to have been used in the Bessemer process.

A sample taken from the cars in 1880 gave:

$Fe = 32.02$; $P = .033$. Authority: 10th Census, p. 169.

The average yield of the mine in its prosperous years was about 14,500 tons.

References: N. J. 1868, p. 575; 10th Census, p. 169; 1883, pp. 103–104; 1886, p. 136.

(*211*) The Baker mine No. 1 was situated about one-eighth of a mile east of the mine referred to in the preceding paragraphs. The original openings were north of the road. In 1868 the vein had been opened for a distance of 100 feet and to a depth of 35 feet. By 1879 these figures had been increased to 225 feet and 110 feet respectively. The mine was worked continuously until about 1880, when it was abandoned. In 1886 a new slope was sunk on the south side of the road to a depth of 200 feet, when ore was encountered. Mining at this place continued until July, 1891. Operations then ceased, although it is reported that at the time of closing drifts had just been driven into a new shoot of ore that had been discovered earlier in the year. The mine was 500 feet deep when work was stopped.

The vein on which the mine was situated was a little east of the one worked on the slope of the hill. Its operators regarded it as the extension of the vein at the Dickerson mine.

The ore body on the north side of the road averaged 9 feet in width, with variations between 2 feet and 20 feet. The ore is reported to have been of Bessemer grade. On the south side of the road the ore body measured 6 feet in width, and dipped 61° southeast. A longitudinal fault is said to have existed in the mine but no descriptions of it are given. The shoot discovered in 1891 was 3 to 5 feet thick. The ore in this was said to be also of Bessemer grade and to contain 60 per cent. of iron.

There have been no analyses of the ore of this mine published, consequently the statements as to its quality cannot be corroborated.

References: N. J. 1868, p. 575; 1873, p. 43; 1879, p. 52; 1880, p. 106; 1882, p. 71; 1883, p. 104; 1886, p. 136; 1891, pp. 242–243.

(212) *The Scrub Oak Mines.*

The Scrub Oak or Dell mines were in Randolph Township, Morris County, in a broad area of strong attraction, about one-quarter of a mile west of the vein of the Baker-Corwin mines, on the west slope of the hill overlooking the plains at Kenvil. The main works were near the south end of the magnetic area, about 2,500 feet north of the northwest shaft of the Baker mine.

Before 1868 the vein had been opened by a series of shafts in a line about 1,000 feet long. The ore was so lean, however, that operations continued only a short time, the mine being abandoned in 1873. It was again opened in 1880 and worked a few months from a pit and a tunnel, during which time 1,680 tons of ore were raised, and again in the summer of 1881, when 820 tons were raised. Nothing more was done until 1899, when negotiations were begun for the erection of a concentrating plant. These having failed a new shaft was sunk in 1905 in the hope of discovering a large body of lean ore. This, however, was soon abandoned.

The ore deposit was from 6 to 20 feet thick in the old shafts and had been proven to a depth of 200 feet. The ore was, however, much mixed with rock, so that it was very lean (Fe=40%), though it contained so little phosphorus that it graded as Bessemer.

The total yield of the mine to June, 1880, was estimated at 56,000 tons.

The breadth of the area of strong attraction and the presence of ore in a number of pits dug northeast of the mine openings point to the existence of an enormous quantity of lean ore in the vicinity of the mine.

References: N. J. 1868, p. 596; 1873, p. 43; 1879, p. 54; 1880, p. 106; 10th Census, p. 170; 1883, p. 106; 1899, p. 161; 1900, p. 206; 1906, p. 176.

(213) *The Erb Mine.*

The Erb mine, in Randolph Township, Morris County, was probably on the same vein as the Scrub Oak mine. It was about one-third of a mile north of the Scrub Oak mine and about one-third of a mile west of the Sullivan mine.

The mine has never been extensively worked. In 1868 the ore body had been sunk on to a depth of 45 feet and had been worked through a length of 60 feet. The mine was abandoned before 1873. It was explored again in 1891 in the hope that the lean ore, which was of Bessemer grade, might be in sufficiently large quantity to warrant the erection of concentrating works. Experiments with the ores, however, did not yield satisfactory results in a commercial sense and the project of concentrating them was therefore abandoned.

The general run of the ore contained 40 per cent. iron and a very little phosphorus. The ore body was 8 or 9 feet broad.

References: N. J. 1868, p. 596; 1873, p. 43; 1879, p. 54; 1891, p. 244; 1896, p. 327; 1899, p. 161.

(214) The J. D. King Mine.

J. D. King mine was on the northeast slope of the ridge west of Wharton, in Randolph Township, Morris County. It was probably on the vein passing through the Scrub Oak and Erb mines to the southeast and the western deposit of the Johnson Hill mine to the northeast.

The mine was probably opened in 1869. In 1871 the same vein was explored further to the southwest near the crest of the ridge, but it was worked for a short time only and then abandoned.

The ore is said to have been good, but since the deposit was very small it could not be mined profitably.

Reference: N. J. 1873, p. 43.

THE IRONDALE MINES.

The Irondale mines comprised a group of about a half dozen mines that were opened on ore bodies lying in the ridge separating the valley of Spring Brook, west of Mine Hill, from Succasunna Plains, and between the road from Dover to Kenvil on the south and the village of Wharton on the north. The mines included within the group are the Corwin, Spring, Sullivan, Stirling, Hubbard, North River, Hurd and Harvey. There

is little in common between most of the mines except their location on the same ridge. The Hurd, Harvey and North River mines were opened on the same vein, but as a rule each mine exploited an ore body that was entirely distinct from those worked by the other mines. The Corwin and Sullivan mines are described below. The other mines are discussed in connection with the mines on the range next east. (Pages 387–392.)

Reference: N. J. 1873, p. 48.

(215) *The Corwin Mine.*

The Corwin mine, in Randolph Township, Morris County, operated a vein a short distance west of the Sullivan mine, and between this and the Scrub Oak vein.

The mine had been worked quite extensively before 1855 by two shafts 100 feet deep, and by 1868 the ore had been removed from a deposit 3 to 10 feet thick for a distance of one-quarter of a mile and to a depth of 200 feet. Its yield at this time was at the rate of about 8,000 tons per year. The dip of the ore body was 45° southeast and its pitch 5° to 6° northeast.

The ore was crumbly (shot ore) and contained specks of pyrite and apatite. An analysis of the average of three specimens yielded:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Met. Iron	Authority
84.7	9.6	.6	.2	61.4	N. J. 1868, p. 576

References: N. J. 1855, p. 207–208; 1868, p. 575–576.

(216) *The Sullivan Mine.*

The Sullivan mine was also one of the Irondale group situated between the Erb and the Spring mines, in Randolph Township, Morris County.

The mine operated on a narrow vein, 1 to 3 feet wide. In 1868 the ore had been removed for a length of 400 feet and to a depth of 40 feet.

The ore is said to have been good.

Reference: N. J. 1868, p. 575.

(217) *The Johnson Hill Mine.*

The Johnson Hill mine was in Rockaway Township, Morris County, on what appears to be the extension of the Corwin and J. D. King vein, north of Rockaway River.

The mine was on the southeast slope of the hill northwest of Wharton. Shafts had been sunk on the vein before 1868, opening it through a distance of about 900 feet and disclosing an ore body from one-half a foot to 6 feet wide. The mine was worked for a short period and then was shut down in 1869. Since this time only surface explorations have been undertaken.

There were reported to be some remarkable faults crossing the vein, but they have not been described because of lack of definite information concerning their character.

References: N. J. 1868, p. 596; 1873, p. 46; 1879, p. 54.

(218) *The Huff Mine.*

The Huff, or Hoff, mine, is in Rockaway Township, Morris County, on the east slope of the same hill as the Johnson Hill mine, and about one-third mile further north.

This mine was worked to some extent before 1855, but at this time had already been abandoned. It was reopened, however, between 1855 and 1868 and worked to a depth of 150 feet, and through a length of about 600 feet, yielding about 50,000 tons of ore. Up to 1870 it was operated intermittently to its full capacity until 1874, when it was shut down. It was again reopened in 1879, but was again closed in the early part of 1880. At the end of this year its total yield had been 78,000 tons, of which 6,000 tons were shipped during the first half of 1880. During the census year (1879–80) 5,015 tons were mined.

The mine was again operated in 1882, but was again abandoned in 1883. It was reopened in 1884 and continued in operation during 1885 and the first half of 1886, at which time it was 200 feet deep, and had supposedly reached the bed rock. This was discovered to be an error by later exploration, which discovered another ore body at a little greater depth, and, consequently, mining was resumed in 1905. Since this time operations

have continued in a small way and a large quantity of ore has been stocked. The present yield is about 12,000 tons annually from a shaft which is about 50 feet vertical and 300 feet long on a slope of 45°.

The ore occurred in a succession of shoots dipping 60° southeast and pitching 35° northeast. These were in two veins separated by from 10 feet to 14 feet of rock. The foot-wall, or west vein, averaged 9 feet in width and the hanging-wall vein 6 feet. Only the foot-wall deposits were mined in 1884, 1885 and 1886, yielding 400 tons monthly. The rock layer between the two veins became thinner with depth.

To the west of the main deposits, *i. e.*, further up the hill, are several old open cuts, which show alternations of ore and rock without any definite walls. Northwest of these again is a vein of hard ore containing considerable quartz. The country rock is a well-banded Pochuck and Byram gneiss containing streaks of magnetite and cut by hornblendic pegmatite.

The ore is rather lean and contains considerable mica. That mined in 1886 averaged about 45 per cent. Fe as it came from the mine. An analysis of carefully selected material taken from the bottom of the mine in 1880 gave:

SiO_2	Fe_2O_3	CaO	MgO	Al_2O_3	TiO_2	P_2O_5	Total	Authority
11.70	77.42	3.19	2.58	2.04	.75	3.10	= 100.75	N. J. 1880, p. 106

$Fe = 54.19$; $P = 1.33$; $S = \text{tr.}$

References: N. J. 1855, pp. 206–207; 1868, p. 597; 1873, p. 46; 1875, p. 35; 1879, pp. 54–55; 1880, p. 106; 10th Census, p. 170; 1883, p. 107; 1884, p. 84; 1885, pp. 99–100; 1886, p. 144; 1899, p. 162; 1905, pp. 319–320; 1906, p. 176.

(219) *The Dolan Mine.*

The Dolan, or Doland, mine was a short distance north of the road between the Richard mine and Berkshire Valley, and west of the Baker and Richard mines in Rockaway Township, Morris County.

It was opened in 1869 by a shaft 120 feet deep, which passed through three small shoots of lean ore. In 1883 it was reopened by a shaft 140 feet deep and operated for four years until it was closed in 1886. The mine was never worked extensively.

The deposit was in two veins 42 feet apart. They dipped 60° southeast, pitched 45° northeast, and were 6 feet to 8 feet wide. The ore contained no sulphur, but there was present in it about 1.5 per cent of phosphorus. About 1,000 tons of ore were raised during 1884 and a small additional quantity in the succeeding year. Most of the work in 1885 and 1886 was for development purposes. A new slope was sunk to a depth of 170 feet and some drifting was done. Most of the mining was in the hanging-wall vein, which was about 8 feet thick. Practically no mining was done in 1886.

References: N. J. 1873, p. 46; 1879, p. 55; 1883, p. 107; 1884, p. 85; 1885, p. 100; 1886, p. 141.

(220) *The Denmark Mine.*

The Denmark mine, in Rockaway Township, Morris County, was not much more than an exploration. It was situated about one-fourth of a mile south of Denmark Pond. Three or four openings have been made in search of ore, and from some of them large quantities of material have been taken. The ore, however, contains considerable pyrite, and very little of it has been removed.

Reference: N. J. 1868, p. 597.

(221) *The Chester Iron Company's Mine.*

The Chester Iron Company's mines were really a series of explorations on the east slope of Copperas Mountain, opposite the south end of Green Pond, in Rockaway Township, Morris County.

Very little was done here to develop the property, which lay southwest of the Green Pond mine. A wide vein of good ore is said to have been discovered between 1870 and 1873 in six pits, but the discovery was not followed up, the place having been abandoned in 1873.

References: N. J. 1873, p. 48; 1879, p. 58; 1883, p. 114.

(222) *The Pardee Mine.*

The Pardee and Canfield mines were just east of Green Pond, at the base of Copperas Mountain, in Rockaway Township, Morris County.

The mines were opened about 1870, very near the contact between the Green Pond conglomerate and the gneiss. A large open cut was made in Pochuck gneiss in a vein which was 15 feet wide and dipped 75°–90° southeast. The ore bodies pitch 25° northeast. The mine was worked for two years, during which time 2,500 tons of ore were shipped, but the cost of transportation to the railroad, which was then 3 miles distant, was so great that the mine was closed in 1872. It was again opened about ten years later and worked until the end of 1884, when it was again closed because of legal contentions.

The ore was compact and hard, and near the surface was free from sulphur. At greater depths pyrite was quite abundant. The ore contained also much mica and hornblende. Within the ore body was found a very fine-grained black, hard rock composed almost exclusively of magnetite and chalcedony.

References: N. J. 1873, p. 48; 1884, p. 89; 1886, p. 149.

(223) *The Winter Mine.*

The Winter shaft was east of Green Pond, in Rockaway Township, Morris County, between the Pardee and Davenport mines, and probably on the same vein of ore. It was worked with the Davenport mine.

The shaft was sunk in 1882 at a distance of 400 yards south of the Davenport mine, on an ore deposit 12 feet wide. A second shaft was sunk in the following year 500 feet southwest of the first one, and within a few yards of the open cut of the Pardee mine. A new deposit was opened up, but before it had been tested the mine was closed down. It was reopened, however, in the spring of 1885, and ore was raised from two shafts on different veins. In the more westerly of these the ore body was 3 feet thick, and in the eastern one 10 feet thick. The mine was again closed before the beginning of 1886.

The ore was coarsely crystalline and rich (65 per cent. Fe) and it carried less pyrite than that of the Davenport mine.

References: N. J. 1883, p. 114; 1884, p. 89; 1885, pp. 102–103; 1886, p. 153.

(224) *The Davenport Mine.*

The Davenport mine was at the eastern foot of Copperas Mountain, on the west side of the road from Marcella, and just southwest of the Green Pond mines, in Rockaway Township, Morris County. To the southwest was the Winter mine.

The mine was opened in 1880 on a vein dipping 40° southeast. At its northeast end the deposit was 12 feet wide, but at its southwest end it was narrower and contained a horse of rock. The mine was worked by pits and through four shallow shafts situated within a distance of 250 feet in a single line, which opened up the vein 450 feet. Operations ceased in the spring of 1884.

The ore contained considerable sulphur, but was otherwise of good quality.

References: N. J. 1880, pp. 108 and 122–123; 1883, p. 114; 1884, p. 89.

(225) *The Green Pond Mines.*

The Green Pond mines, like the Pardee, Winter and Davenport mines, were in Rockaway Township, Morris County, at the east base of Copperas Mountain, near the contact of the Green Pond conglomerate and the gneisses. They were a short distance northeast of the Davenport mine.

The mines were opened in 1872 by several pits and a trench, which exposed a width of 50 feet of ore dipping about 40° southeast. In the first year 3,000 tons of ore were removed. Explorations were continued during the succeeding year and new openings were made both north and south of the earlier ones. These resulted in the uncovering of the vein for a distance of a mile north of the road crossing the mountain from Marcella. The mines were operated with slight interruptions until about 1882.

Between 1879 and 1880 about 18,000 tons were raised. In 1899 the property was again explored, and this time in a more systematic manner than had heretofore been the case. Preparations for mining were begun and continued through the following year, and about 1,200 tons of ore were obtained. In consequence of dullness in the ore market, however, operations were then suspended.

In the original mines, which were south of the explorations of 1874, there were four open pits, from three of which the ore was quarried at the rate of about 75 tons per month. In the large pit at the south end of the property the ore was in a broad shoot pitching steeply toward the northeast. In 1880 two shoots were worked to a depth of 320 feet, a third to a depth of 125 feet, and a fourth to a depth of 85 feet. At the south end of the mine the ore was not more than 200 feet from the conglomerate. Its dip was 25° to 30° southeast. Further north the dip became flatter. The deposit was 70 feet high and 20 to 25 feet thick. About 250 yards farther northeast the dip was 40° southeast and the pitch 30° northeast. The main deposit was 20 feet wide, but in the foot-wall was another deposit 3 feet thick.

In 1899 there were three slopes working. No. 1, to the southwest, was 360 feet deep, measured on the slope. No. 3 was 74 feet northeast of No. 1, and the ground between the two was all ore. Magnetic observations showed that the vein extended for a considerable distance farther to the northeast, beyond the point where the northeasternmost openings had uncovered it. Without doubt the explorations already made at this place indicate the existence of a large quantity of ore of fair quality. It is rumored that the property is to be reopened in the near future.

The ore from the entire mineralized zone contained pyrite and some green mica, except near the surface, but it was so low in phosphorus that it was used for Bessemer pig. A sample taken from a carload representing the product of the four pits being worked in 1880 gave:

$Fe = 51.33$; $P = .033$. Authority: 10th Census, p. 174.

References: N. J. 1873, pp. 48–49; 1874, pp. 23–24; 1879, pp. 58–60; 1880, p. 108; 10th Census, p. 174; 1886, p. 141; 1899, pp. 157–158; 1900, p. 204.

(226) *The Copperas Mine.*

The Copperas mine in Rockway Township, Morris County, was at the east base of Copperas Mountain, near the head of Timber Brook, on the west side of the road between Newfoundland and Split Rock Pond, very near the point where, later, the Green Pond mines were developed.

During the war of 1812, with England, it was worked for the purpose of making copperas and red paint, but it has not been worked for iron ore. The magnetite was much mixed with pyrite.

Reference: N. J. 1868, p. 597.

The Bancroft Shaft.

The Bancroft shaft was near the road crossing the mountain at the head of Green Pond, about one-quarter of a mile northeast of the openings of the Green Pond mines, in Rockaway Township, Morris County.

Explorations were made here in 1874 on apparently the same veins as those mined at the Green Pond mines.

References: N. J. 1874, p. 25.

(227) *The Howell Tract Exploration.*

The Howell Tract explorations were northeast of the Green Pond mines, a few hundred yards east of the road to Newfoundland, in Rockaway Township, Morris County.

A line of attraction crosses the property. On this a trial shaft was dug between 1874 and 1879, and from 50 to 100 tons of ore were taken from it. The place was again worked in 1880 for a short time, but nothing of importance was ever developed. The mine was again working in 1885, at which time there were four shafts in operation. Of these two were on each of two different parallel veins. Very little ore was raised and the mines were again closed at the end of the year. The ore contained 55 per cent. Fe and considerable sulphur and phosphorus. The dip was 50° southeast.

References: N. J. 1879, p. 60; 1880, p. 108; 1885, p. 103; 1886, p. 144.

The Wild Cat Mine.

The Wild Cat, or Kitchell, mine was northeast of the Howell mine, on the east side of Copperas Mountain, in Rockaway Township, Morris County.

Two veins of ore were opened about 1877 by five test pits and a small quantity of ore was obtained. Nothing more was done until 1885, when explorations were begun in earnest and continued during the succeeding year, a few tons of ore being raised. The property was then closed down.

When work ceased in 1886 there was a shaft at least 75 feet deep, three slopes, one of which was 35 feet deep, and an open cut 40 feet deep, besides a tunnel. The ore was found in two veins. In one of these, called the "Rich vein," it contained 65 per cent. Fe and no sulphur, and was said to be of Bessemer grade. The ore of the other vein was lean and pyritiferous. The dip of the ore body was 40° southeast and its pitch 22° northeast. Its width in the open cut was 5 feet. The ore contained hornblende and mica.

References: N. J. 1879, p. 60; 1885, p. 103; 1886, p. 146.

(*228*) *The Vreeland Mine.*

The Vreeland farm exploration was at the base of the east slope of Kanouse Mountain, about midway between Charlottesburg and Echo Lake, in West Milford Township, Passaic County.

A few holes were dug 35 to 40 feet deep about 1878, in which ore was found that was like that at the Green Pond mines. No mining was attempted.

Reference: N. J. 1879, p. 61.

THE MINE HILL BELT.

The deposits in the vicinity of Mine Hill, Wharton and Mount Hope are the most notable feature in the geology of the magnetite ores in New Jersey. Nowhere have so many ore bodies been found so crowded together, and nowhere else have so many large mines been developed within such a small area. South of Rockaway River the country is honeycombed by almost continuous lines of openings with scarcely any unworked ground between

them (Plate VIII). North of the river the openings are less numerous, although the land has been thoroughly explored to the Hickory Hill mines, the northern openings of which are four miles from the river.

The productive area which varies from one-quarter to one mile in width, contains a large but undetermined number of veins, of which some have yielded great quantities of ore. The Dickerson, Byram, Baker, Stirling, Hurd, Mount Pleasant, Richard and Mount Hope mines are all in this region and all have played an important part in the mining history of the State.

On Mine Hill and near Wharton the mines are on three or more distinct groups of veins or ranges, as follows, beginning with the westernmost:

1. The Canfield, Baker, Corwin, Erb, J. D. King, Johnson Hill and Huff mines. The Scrub Oak mine is about one-quarter of a mile west of the Corwin mine, probably on a distinct vein. It is included here simply as a matter of convenience.

2. The Black Hills, Dickerson, Baker No. 1 and Sullivan mines.

The mines of these two lines have been regarded as belonging to the High Bridge belt and have already been described (pages 358–368).

3. The Van Doren, Bryant, C. King, King, McFarlands, Evers, Brotherton, Byram, Baker, Millers, Randall Hill, Jackson Hill, Stirling, Hubbard, Harvey, Hurd, Orchard, Washington Forge, Mount Pleasant, Baker, Richard, Allen, Teabo, Mount Hope and Hickory Hill mines and two unnamed mines explorations to the northeast. This line of mines is the most important of the three. It is a part of the Mine Hill belt, which stretches from the Bryant mine on the south to the Charlottesburg mine on the north, a distance of about 15 miles (Plate VIII) with an exploration near the State line, 12 miles farther northeast, which perhaps may be considered as being on this line. In view of its remoteness, however, its assignment to the Mine Hill belt is not beyond question.

The Mine Hill belt has, in the past, been one of the most productive in the State, yielding immense quantities of ore, and it is still productive at the Hurd, Orchard, Richard and Mount Hope

mines, having furnished over 50 per cent. of the ore raised in the State during 1909 and several preceding years.

South of Wharton the belt has been proven to be practically continuous for several miles, and wherever opened it has yielded ore of commercial value. Since, however, ore has been taken from shallow depths only, except at the Hurd mine, it is probable that there still remains in this portion of the belt a large reserve of good material.

(229) *The Van Doren Exploration.*

It is probable that this exploration was on the south side of the road between Succasunna and Mt. Freedom, opposite the Bryant mine, in Randolph Township, Morris County.

The place was worked in 1873, but further than this nothing is known about it.

Reference: N. J. 1879, p. 50.

(230) *The Bryant Mine.*

The Bryant mine was near the southwest end of the east range of the Mine Hill belt of mines. It was in Randolph Township, Morris County, about 1.5 miles southeast of Succasunna, between the two roads connecting this place with Mt. Freedom.

The place was not extensively worked before 1868, although at this time an ore body 3 feet thick had been mined to a depth of 100 feet and uncovered for a distance of 700–800 feet. The mine was closed before 1873, but was reopened in 1876 and operated continuously until 1883. From this time it remained idle until 1886, when it was reopened and worked for a short period. By 1890 it had been abandoned.

When the mine was closed in 1883 there were five slopes, of which the deepest went down in the "bottom rock" for a distance of 735 feet. The ore deposits consisted of five shoots, one above the other, ranging from 10 feet to 25 feet in height and from 2 feet to 8 feet in width. All dipped about 60° southeast and pitched 25°–33° northeast. The shoots were separated by pinches through which narrow strings of ore extended, connecting the shoots with one another.

The ore was high in iron and low in sulphur. Samples taken from the two shoots being worked in 1880 gave results as below:

Ore from shaft No. 1—*Fe*=63.24; *P*=.038; TiO_2=present. 10th Census, p. 167
Ore from shaft No. 2—*Fe*=50.70; *P*=.025; TiO_2=present. 10th Census, p. 167

During the five years between 1876 and 1880 the total yield of the mine was 22,400 tons.

References: N. J. 1868, p. 566; 1873, p. 43; 1879, p. 50; 1880, p. 104; 10th Census, p. 167; 1883, p. 98; 1886, p. 138.

(231) *The Foulon Mine.*

The Connor-Foulon, or Connor Fowland, mine was the northeast extension of the Bryant mine, in Randolph Township, Morris County. It lay between the Bryant and the C. King mines, on the opposite side of the road from the former.

It was worked for a short time before 1868, and closed before 1873.

References: N. J. 1868, p. 566; 1873, p. 43; 1879, p. 50.

(232) *The Chas. King Mine.*

The Chas. King mine was in Randolph Township, Morris County, between the Foulon and King mines, on the north side of the road between Mt. Freedom and Succasunna. It was really the northeast extension of the Foulon mine.

The vein, which was 2 feet thick, had been uncovered for a length of about 200 feet before 1868, but the mine had not been worked to any extent. It was abandoned about 1870.

References: N. J. 1868, p. 566; 1873, p. 43; 1879, p. 50.

(233) *The King Mine.*

The King mine was also in Randolph Township, Morris County. It was situated about three-fourths of a mile northeast of the Chas. King mine, a few hundred yards south of the McFarland mine and about one-third of a mile south of the Dickerson mine, on the west side of the road running south from Ferro Mont.

Before 1853 the mine had been opened to a depth of 30 feet, exhibiting three layers of ore, dipping 54° southeast, and pitching 50° northeast. The top layer was 4 feet thick, the second 8 feet, and the third was a lean magnetitic pegmatite of undetermined thickness. The rock between the ore was generally micaceous. The upper two layers of ore contained some apatite, but were otherwise of good quality. The mine was abandoned before 1873. It was re-opened later, and was being operated in 1879 and intermittently during 1880, yielding 2,560 tons of ore. At the close of this year it was abandoned permanently.

References: N. J. 1855, p. 220; 1868, p. 566; 1873, p. 43; 1879, p. 50; 1880, p. 105; 10th Census, p. 167; 1883, p. 98; 1890, p. 97.

(234) *The McFarland Mine.*

The McFarland mine is merely an exploration. It was situated on the opposite side of the road from the King mine, in Randolph Township, Morris County, and probably on the same vein.

There were evidently several shoots of ore on the property, but they have not been worked since 1868.

References: N. J. 1868, p. 566; 1873, p. 43; 1879, p. 50.

(235) *The Evers Mine.*

The Evers mine was a few hundred yards east of the north end of the McFarland pit, in Randolph Township, Morris County, probably on a vein that was east of the McFarland vein.

Though the vein averaged only 1.5 feet in width and was rather lean, it had been worked for a length of 300–400 feet, and to a depth of 230 feet before 1868. Before 1873 the mine was abandoned, but it was opened again in 1879 and worked until 1883.

The later ore was reported to be rich, but on account of the small size of the vein it was unprofitable to work except when the price of ore was comparatively high. Between June, 1879, and June, 1880, about 2,500 tons of ore were produced, principally from near the surface, as the deeper workings at this time had not been pumped out.

A sample of the shipping ore taken from the cars by the agents of the 10th Census gave:

Fe = 47.86; *P* = .086; TiO_2 = present. Authority: 10th Census, p. 167.

References: N. J. 1868, pp. 566–7; 1873, p. 43; 1879, p. 50; 10th Census, p. 167; 1883, p. 98; 1884, p. 82.

(236) *The Brotherton Mine.*

The Brotherton mine was northeast of the Evers mine, and one-fourth of a mile south of the Byram mine, on both sides of the road between Mt. Fern and Kenvil, in Randolph Township, Morris County.

The mine is an old one. It was opened before 1855, but was not in operation during that year. By 1868, however, it had been worked to a depth of 200 feet for a length of 400–600 feet on a vein from 2 feet to 5 feet wide. Before 1873 the mine was closed. It was reopened in 1879 and worked to yield 650 tons monthly until June, 1880, when it was again shut down, after producing 4,730 tons of ore from five shafts, of which the deepest was down 130 feet. The lease was abandoned in 1882. In 1900 preparations were made for resuming work, but no ore was raised. In the following year the preparations were continued, the main slope was sunk 75 feet, and 200 tons of ore had been raised when operations ceased.

In the development of the mine two small veins were encountered, separated by a few feet of barren ground. The ore as it came from the mine was mixed with considerable rock. Its composition, as reported in 1868, was:

Fe_3O_4	SiO_2 *and ins.*	*S*	P_2O_5	*Met. Fe*	*Authority*
89.8	8.3	0.0	tr	65.0	N. J. 1868, p. 567

A sample of the cobbed ore ready for shipment in 1880 gave:

Fe = 50.98; *P* = .214; TiO_2 = present. Authority: 10th Census, p. 168.

Other samples tested by Messrs. Booth, Garrett and Blair showed the presence of 0.11 per cent. of phosphorus.

References: N. J. 1855, p. 215; 1868, p. 567; 1873, p. 43; 1879, p. 50; 1880, p. 105; 10th Census, p. 168; 1883, p. 99; 1884, p. 82; 1890, p. 97; 1899, pp. 161 and 169; 1900, p. 204; 1901, p. 140.

(237) *Canfield's Phosphate Mine.*

Canfield's Phosphate mine, in Randolph Township, Morris County, about one-fourth of a mile northeast of the Dickerson mine, is a magnetite mine, in which the ore is so full of apatite as to be worthless for smelting purposes. It is apparently in a vein that lies about midway between that of the Dickerson mine and that of the Brotherton mine.

The mine was opened in 1870, and was explored to some extent in that year by two shafts, one of which was 40 feet deep. The ore deposit, which is 8 feet wide, dips 65° southeast, and is cut by a fault, causing a displacement of about 35 feet to the left, carrying the northeast extension of the ore bed to the northwest side of the road, *i. e.*, on the opposite side from the shafts, which are on the southeast side. The vein is traceable for 1,000 feet to the southwest by a magnetic line.

The ore is a granular aggregate of magnetite and grayish apatite, which are arranged in some places in alternating layers. A little quartz, orthoclase and biotite are also present in the ore to some extent. In bulk the magnetite and apatite are in equal parts, and in weight the ore carries about 35 per cent. of the phosphate. Analyses of an average ore showed the presence of 31.90 per cent. of apatite, while another of a sample rich in phosphorus gave a percentage of 53.85 per cent. apatite.

The result of an analysis of what was considered an average ore gave (N. J. 1870, p. 35):

SiO_2 and ins.	*Magnetite*	*CaO*	*MgO*	*SaO_3*	*P_2O_5*	*Total*
11.30	54.01	17.21	1.65	0.07	14.91	= 99.15

Since the CaO was not in sufficient quantity to satisfy the P_2O_5 shown by the analysis, and, further, since the acid solution of the magnetite contained some phosphoric acid and no lime, it was thought that some of the phosphorus in the ore was combined with some of the iron.

Experiments were made in separating the apatite from the magnetite by the use of sulphuric acid in the hope that a method might be discovered for the production of a phosphate sufficiently cheap to make the ore a valuable source of commercial

fertilizers. While such a method was suggested as would result in a profit of $30.60 per ton of apatite removed, the matter was not further developed.

In 1891 a new shaft was sunk and the property was further explored with a view to securing large quantities of material that might be separated into marketable magnetite ore and apatite. The project, however, was not successful, and the mine was abandoned.

References: N. J. 1871, pp. 34-38; 1873, p. 43; 1879, p. 51; 1891, p. 242.

(238) *The Byram Mine.*

The Byram mine was formerly one of the most important in the State. It is in Randolph Township, Morris County, between the Brotherton and Baker mines, 2.5 miles west of Dover.

The mine was probably opened before 1844, as it is known that in this year the first steam engine ever used in a New Jersey iron mine was installed at this place by John Byram.

The mine was worked extensively before 1855. In this year it was about 200 feet deep and 600 feet long, and was yielding about 30,000 tons per year. The mine was worked continuously until 1883, when it was abandoned. The depth of the slope through which most of the ore was raised had reached 1,100 feet measured on the dip of 60°. As the deposit at the bottom was small, and the shoot from which the ore was being obtained was short, the expense of mining became too great to warrant further operations.

In 1879 ore was also being raised from a vein southeast of the main vein. Work was continued on this until 1883, when this too was abandoned and the whole mine became idle.

When the mine was most actively operated (in 1880) it consisted practically of two independent propositions. At the southwest mine, shaft No. 7 was in a shoot 18 feet west of the main shoot, which was entered by three shafts that were northeast of No. 7 and were connected underground.

The northwest openings comprised two slopes known as the Byram and the Russell. They followed the foot wall of the deposit which dipped 50° southeast. These were worked only a

short time during this year, as fire destroyed the engine house at about the time the shafts were to have been put in commission.

Between 1870 and 1883 the total shipments from the various openings aggregated 157,376 tons.

The ore deposit in the Byram mine was notable for the large number of faults that intersected it. The main deposit was 3 to 8 feet thick and it dipped 50° southeast. It was crossed by at least 6 faults, of which the southwestern one was 130 feet from the end of the mine. At a distance of 36 feet northeast of this was a second with a throw of 1.5 feet. The next was 153 feet further northeast and had a throw of 14 feet. At 110 feet further along was a fourth, producing a displacement of 6 feet, and 29 feet beyond was a fifth, with a displacement of 5.5 feet. The sixth was 27 feet from the fifth, with a throw of 8 feet. In all cases the displacement was to the left. Two of the faults were vertical: the others dipped steeply to the southwest (Fig. 19).

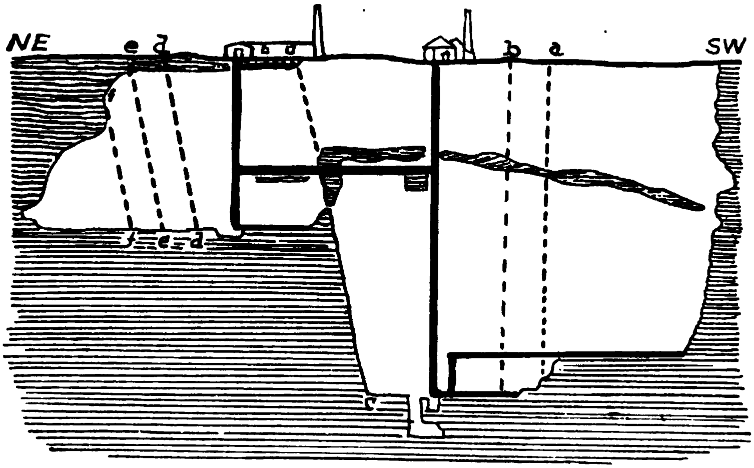


Fig. 19.

Vertical section of Byram mine. Dotted lines represent faults. Unshaded area, ore removed. Shaded area, ore and rock. Heavy black lines, slopes and drifts.

The ore was crumbly and much mixed with apatite. In many specimens the phosphate appeared to constitute one-half its bulk. In spite of this fact the analysis of the ore quoted in the Report of 1868 showed the presence of 88.07 per cent. Fe_2O_3 and only a

trace of phosphorus. Later analyses, however, indicate that apatite was quite abundant.

	Fe	*P*	*TiO_2*	*Authority*
I,	38.52	0.393	Present	10th Census, p. 168
II,	28.24	0.605	Present	10th Census, p. 168
III,	40.70	0.790		10th Census, p. 168
IV,	59.54	0.245		10th Census, p. 168
V.	57.75	2.110		10th Census, p. 168

I.—Sample cobbed ore from shaft No. 7.
II.—Sample cobbed ore from shaft No. 12, northeast of No. 7.
III.—Sample cobbed ore from shaft No. 6, northeast of No. 12.
IV.—Sample coarse, granular ore, 4-8 in. wide, near hanging wall.
V.—Sample from pillar in Byram slope.

References: N. J. 1855, pp. 211–215; 1868, pp. 567–569; 1873, pp. 43–44; 1879, p. 51; 1880, p. 105; 10th Census, p. 168; 1882, p. 70; 1883, p. 99; 1884, p. 82.

(239) *The Baker Mine.*

The Baker mine (the southeast Baker of the Report of 1868) was in Randolph Township, Morris County, just northeast of the Byram mine and southeast of the Millen mine.

The mine was in the same general range as the Byram, Chas. King and Bryant mines, but its ore came from a vein that lay further west, possibly on the vein that yielded ore at the King and McFarland mines. The mine was worked before the year 1868 to the depth of 100 feet on a deposit from 5 to 6 feet wide. It was closed during 1868, but was apparently reopened a few years later and operated for a short time. It was idle in 1879 and had then been abandoned for several years.

References: N. J. 1868, p. 570; 1879, p. 52.

(240) *The Millen Mine.*

The Millen, or Mellen, or Millon, mine, in Randolph Township, Morris County, is on Mine Hill, a few hundred yards south of the road between Dover and Kenvil. A few hundred yards to the south of west is the Baker mine, and a few hundred yards to the southwest is the Byram mine. Further south, on the strike of the Millen vein, are the openings of the Brotherton mine.

The Millen mine was opened and abandoned before 1855. During this early period of activity the ore had been removed

to a depth of 130 feet. It was reopened shortly after this year and by 1868 it had been worked to a depth of 250 feet and for a length of 200 feet in an ore body that was 2 feet to 5 feet wide on the surface, and gradually widened to 5 feet below. Its dip was very steep to the southeast. The vein contained a small horse of rock and was cut by a transverse fault that caused an offset of a few feet. In some places the ore and rock passed into one another through repeated alternations of seams of the two substances.

The mine was closed shortly after 1873. It was again reopened in 1880 and worked until 1883, when it was abandoned. In 1880 ore was being raised through a shaft 255 feet deep. During the census year 1,263 tons were mined. Its total yield was probably large, though we have no figures that give us any accurate idea of its magnitude.

A sample of ore taken from several carloads by the chemists of the 10th Census gave:

$Fe = 43.73$; $P = .583$. Authority: 10th Census, p. 169.

References: N. J. 1855, pp. 210–211; 1868, pp. 564–565; 1873, p. 43; 1879, p. 51; 1880, p. 105; 10th Census, p. 168–169; 1884. p. 83.

The Hance Mine.

The Hance mine was simply the extension of the line of attraction passing through the Millen mine. So far as is known it was never worked.

Reference: N. J. 1868, pp. 565–6.

(241) The Randall Hill Mine.

The Randall Hill mine was an important one prior to 1868. It is in Randolph Township, Morris County, on the strike of the Byram vein and about one-eighth of a mile north of the Millen mine.

Two deposits were worked before 1855 through a shaft 300 feet deep. The mine was, however, abandoned before this date. Shortly afterwards it was reopened and worked intensively. By 1868 the workings had been extended for a distance of 600 feet

and to a depth of 450 feet on a dip of 45°. Operations continued until 1882, when the mine became so deep that it was no longer possible to raise ore with profit. It was then abandoned.

The ore came from three parallel veins, of which the largest measured from 2 to 8 feet in thickness. These were cut by a number of faults with throws to the right (see Fig. 20).

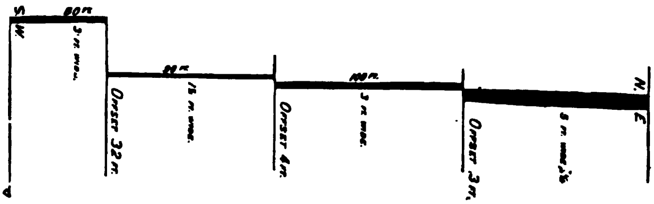


Fig. 20.

Plan of faults at the Randall Hill mine. (From Ann. Rep. State Geol. N. J. for 1883, p. 63.)

In 1880 the deposits were worked through two slopes, of which one was 700 feet deep and the other 300 feet deep. Between the two was a fault with a throw to the right of 21 feet. At the deepest point in the mine the deposit was 3 feet to 3.5 feet thick.

A sample of the ore taken from the cars in 1880 analyzed:

$Fe = 44.51$; $P = .577$. Authority: 10th Census, p. 169.

In the census year 1879–1880 the mine produced 8,360 tons of ore.

References: N. J. 1855, p. 210; 1868, p. 570; 1873, p. 43; 1879, p. 51; 1880, p. 105; 10th Census, p. 100; 1882, p. 70; 1883, p. 100.

(242) *The Jackson Hill Mine.*

The Jackson Hill mine in Randolph Township, Morris County, was another important mine fifty years ago. It worked the northeast extension of the Randall Hill mine, all the way down the northeast slope of Mine Hill, a distance of about 1,000 feet.

The mine was worked before 1855 and abandoned. It was again opened before 1868 and worked until about 1876, when it was again abandoned, as the workings had reached the property line.

The vein, which was exploited to a depth of 125 feet, varied greatly in thickness, that portion which was worked being from 10 to 14 feet wide.

References: N. J. 1855, p. 210; 1868, p. 570; 1873, p. 43; 1879, p. 51.

(243) The Spring Mine.

The Spring mine, in Randolph Township, Morris County, is one of the Irondale group (see pages 366-367). It was east of the Corwin mine and west of the Jackson Hill mine, in the valley of Morris Spring Brook.

The mine was apparently on a distinct vein not connected with that worked by any other mine. It was in active operation during 1868, at which date it had removed the ore from a 3 to 5-feet-thick deposit to a depth of 50 feet and through a length of 400 feet. The ore is said to have been of good quality. Shortly afterward the mine was abandoned.

Reference: N. J. 1868, p. 575.

(244) The Stirling Mine.

The Stirling, New Stirling, Hubbard and North River mines worked the same group of ore bodies, and were so intimately connected that it is difficult to discuss them separately (Fig. 21).

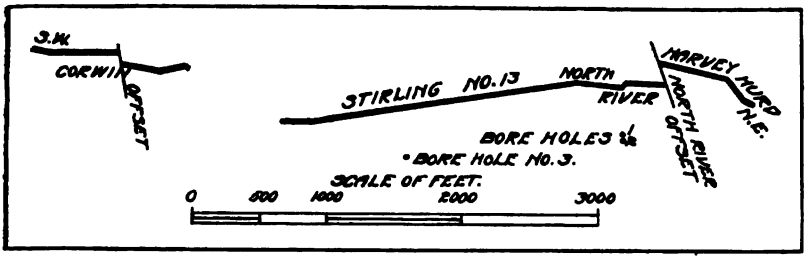


Fig. 21.

Plan of ore vein and faults at the Stirling Mine, Wharton. (From a map and survey by L. C. Bierwirth.)

They were all situated in Randolph Township, Morris County, just south of Wharton.

The Stirling mine is the best known of the Irondale group of mines. Its southernmost shaft is a few hundred yards northeast of the Spring mine, and its northernmost shaft about the same distance southwest of the Hubbard mine. The Hubbard and North River mines worked the same shoot, which lay above the Stirling shoot and further northeast. The Hubbard mine was on its southwest end and the North River mine at its northeast end. The New Stirling was a slope situated on the Hubbard property, through which was worked the northeast end of the Stirling shoot, which at this place was beneath the Hubbard-North River shoot (see page 369).

According to C. T. Jackson the Stirling, or Sterling, mines were first worked by a party of Nassau miners in 1640. However this may be, the mine was operated long before 1855, and by 1868 had yielded about 150,000 tons of ore. From this time it was worked almost continuously until 1885.

The ore deposit varied greatly in width. It possessed a dip of 30°–45° southeast and pitched 10°–18° northeast. In 1855 the vein had been opened for a distance of 300 feet to a depth of 100 feet. In 1868 the depth of the mine had increased to 250 feet and its length to 600 feet. The principal shoot on which the early mining was done had been followed about 1,500 feet by 1879. Its total length was later found to be 1,800 feet, its average thickness 7 feet and its height between 90 feet and 150 feet. The dip of its foot wall averaged about 45° southeast and the pitch of the bottom rock 15°–18° northeast. At the bottom of the mine, when work stopped, the ore had pinched to a foot in width. Drill holes put down vertically at 385 and 415 feet southeast of the outcrop of the North River shoot found ore at 338 feet and at 365 feet from the surface. This was regarded as indicating that the Stirling shoot extends northeastward under the North River mine, *i. e.*, that a second shoot lies under that of the North River mine.

The ore was crumbly, was much stained with limonite and contained considerable apatite, the quantity of this mineral being much greater in the middle stopes than in the end stopes. A sample of the ore taken from the cars in 1880 gave:

$Fe = 58.80$; $P = 1.342$. Authority: 10th Census, p. 170.

It was supposed by the miners that a great fault separates the deposit at this mine from that at the Corwin mine to the southwest and that both mines are situated on the same vein, although the interval between them is 700 feet and in this distance no ore has been found. It is now known that a fault with a throw of 75 feet to 80 feet to the right exists between the two deposits, but that this is sufficient to account for the more eastern situation of the Stirling shoot is doubted.

References: Proc. Bos. Soc. Nat. Hist., Vol. IV, 1854, p. 308; N. J. 1855, pp. 206–207, 208–209; 1868, pp. 576–577; 1879, p. 52; 1880, p. 106; 10th Census, pp. 170; 1883, pp. 104–105 and 151; 1884, pp. 85–86; 1885, p. 100; 1891, p. 243.

(245) *The Hubbard and North River Mines.*

The Hubbard and North River mines were on the same deposit. The Hubbard, which was on the southern end of the vein, was situated a few hundred yards north of the Stirling mine. It occupies about 600 feet of the vein (Fig. 21). The North River mine exploited about 300 feet further north. Both mines were opened before 1855. By 1868 the ore had been removed by the operations of the Hubbard mine to a depth of 200 feet at the rate of 6,000 tons per year. The North River mine had taken from its portion of the deposit about 20,000 tons.

The ore body in which the mines were situated varied in width from 1 foot to 14 feet and dipped 30°–45° southeast. The foot-wall at the Hubbard mine was a coarse granite, probably a pegmatite.

At the north end of the deposit, *i. e.*, at the north end of the North River mine, was a fault with a throw to the left of 130 feet, which separated this ore body from that worked at the Harvey mine.

The only analysis of the ore published is an old one, which is probably not trustworthy. It is as follows:

Fe_3O_4	*SiO_2 and ins.*	*S*	*P_2O_5*	*Metal. Iron*	*Authority*
88.08	2.40	.0	tr	63.8	N. J. 1868, p. 578

References: N. J. 1855, pp. 205–206 and 209–210; 1868, pp. 577–578; 1883, p. 105 (North River).

The new Stirling mine was opened in 1890 to obtain the ore in the northeast portion of the Stirling shoot lying beneath the North River shoot.

The shaft was located 75 feet southwest of the North River fault referred to as limiting the North River workings to the northeast. It was put down at an angle of 45°, striking the ore deposit at a depth of 200 feet, where it dipped 20° southeast. The slope was continued until it was 603 feet deep. Here the deposit was tapped by a drift of 28 feet driven into the hanging-wall. The ore body was found to vary between 3 feet and 18 feet in width, to dip 48° southeast and to pitch northeast. It yielded a 60 per cent. non-Bessemer ore at the rate of 90 tons daily. The mine was worked until 1900, since which time it has been operated in conjunction with the Hurd mine.

In 1897 a drift was driven through the fault, and a body of ore 10 feet wide and several hundred feet long was developed on the northeast side of the offset under the Harvey deposit. Practically all of the ore had by this time been taken from the Stirling shoot, so that the later developments were confined to the ore northeast of the fault. The deposit between the fault and the old Hurd mine was discovered to be a large shoot between 6 feet and 12 feet wide and 60 feet high, which lay under the original Hurd shoot. The ore was taken out partly through the New Stirling slope but mainly through the Hurd shaft. (See Hurd mine, p. 391.)

References: N. J. 1890, p. 60; 1891, p. 243; 1897, p. 323; 1898, p. 236; 1899, p. 155; 1900, p. 201; 1901, p. 140; 1902, p. 119.

The Harvey and Hurd (246) Mines.

The Harvey and the Hurd mines were originally two separate mines on the same ore shoot, which was probably the continuation of the North River and Stirling shoots northeast of the fault which has been described as being north of the North River mine. The Harvey was to the southwest and the Hurd to the northeast. (Fig. 21.)

The Harvey mine was opened, worked and abandoned before 1855. It was evidently reopened shortly after this time, for it is

described as being 400 feet long, 300 feet deep and from 2.5 to 10 feet wide in the Report of 1868. Shortly after this time the workings of the Harvey and the Hurd mines opened into one another and the former mine lost its identity.

The Hurd mine has been one of the most prolific producers in the State. By 1868 it had been worked for a distance of 100 feet to a depth of 70 feet. The mine was closed shortly thereafter, and was reopened in 1872. Work was again stopped in 1874 by the influx of a great quantity of water. In 1877 an adit was constructed to drain the mine, and also the Orchard mine, which lay a little farther north. This adit was completed in 1879, and mining was resumed. Operations were continued until 1883, when the mine was again shut down. It was not idle long, however, as we find it again active in 1886. In spite of these intervals of idleness, it produced nearly 450,000 tons between 1867 and 1886. From this time until 1897 it was worked intermittently, yielding a small quantity of ore nearly every year. In 1891 a small concentrator, with a capacity of 60 tons daily, was erected for the purpose of concentrating the lean ore culled from the general product of the mine and to convert it into a 60 per cent. Bessemer ore.

In 1897 ore was found under the old Hurd workings by the drift driven from the New Stirling mine. In this year also the concentrator was destroyed by fire. It was never rebuilt. In the following year the ore found in 1897 was explored for a distance of over 100 feet above the 5th level of the New Stirling mine, where it became too narrow to work profitably.

Mining was continued on this deposit through the succeeding few years. In 1901 ore was taken through the Hurd slope—the deposit northeast of the slope, where most of the work was done, being 65 feet high and 2.5 feet to 6 feet wide. Its pitch was 400 feet in a horizontal distance of 1,150 feet. In 1902 about 20,000 tons of ore were raised, and in the following year about 15,000 tons.

During 1904 the property passed into the possession of Jos. Wharton, since which time it has been worked to supply the Wharton furnace.

This year and the following one were devoted principally to exploration. In the latter year (1905) a new deposit 15 feet wide was discovered, and since this time the mine has been a comparatively large producer.

The deposits mined in the early years of the mine's history were rather narrow, rarely exceeding 9 feet in width. Their dip was about 52° southeast, and their pitch, as usual, northeast. The old shoot was 100 to 130 feet high. The dimensions of the shoot being worked at present have not been divulged. It is known, however, that it is large.

A sample of the ore from 50 tons on the cars in 1880 gave:

$Fe = 57.11$; $P = 1.618$. Authority: 10th Census, p. 170.

References: N. J. 1855, p. 206; 1868, p. 578; 1879, pp. 54–54; 1880, p. 106; 10th Census, p. 170; 1883, p. 105; 1886, p. 145; 1890, p. 60; 1891, p. 243; 1896, pp. 326–327; 1897, pp. 322–323; 1898, p. 236; 1901, pp. 140–141; 1902, p. 119; 1903, p. 102; 1904, p. 296; 1905, p. 317; 1906, p. 176.

(247) The Orchard Mine.

The Orchard mine was north of the Hurd mine, in Randolph Township, Morris County, on a vein running from the Morris Canal to the Rockaway River.

The mine was opened some time in the middle of the last century (about 1850), and up to 1868 had produced 50,000 tons of ore from workings that were 400 feet long and 300 feet deep. In 1874 water caused a stoppage of work, but in 1879, after the completion of the drainage tunnel referred to in the description of the Hurd mine, operations were resumed and continued until 1884, the product averaging about 12,000 tons annually. At this time the mine was 700 feet deep and 1,000 feet long. Its total yield to June, 1880, was estimated to be 220,000 tons. In 1886 the mine was reopened with an output of 1,500 tons monthly. In 1890 a drift 800 feet long was driven to the southeast from the 700-foot level to intercept the Richard vein, but only a thin seam of ore was found, which was supposed to be the extension of the Jackson Hill deposit. The mine was closed in 1893.

Recent work in the Hurd mine has shown the presence of unexpected deposits beneath those formerly worked at the Orchard

mine, and, consequently, this mine was reopened in 1907, and mining was resumed at the close of 1908.[1]

The vein in this mine is thought to be the northeast extension of that in the Hurd mine. There is no faulting in the mine, but the shoot structure is well developed. The deposit averaged about 5 feet in thickness. It had a dip of 48° to 57° southeast and a pitch of 30° northeast. Under the Rockaway River the deposit was cut off by a fault, which is thought to offset the ore about 150 feet to the right. According to this view the Washington Forge mine, which is northeast of the Orchard mine, on the north side of the river, is on its continuation. The extension of the Orchard deposit has been sought on the north side of the river in the line of strike of the ore body on its south side, but without success. Moreover, no ore was found on the southwest extension of the Washington Forge mine on the south side of the river. Consequently the assumption of a fault between the two mines is thought to be well founded.

The country rock is a light gray Byram gneiss, containing streaks of black gneiss, which is impregnated with magnetite along definite bands. In the magnetite are vugs of quartz, and veins of quartz and hornblende are often interbanded with others of pure magnetite.

The ore contained about 59 per cent. of iron and was rich in phosphorus (about 1.5 per cent.). A sample obtained from the cars in 1880 gave:

$Fe = 55.0\%$; $P = 1.722$. Authority: 10th Census, p. 170.

References: N. J. 1868, p. 578; 1879, p. 54; 1880, p. 106; 10th Census, p 170; 1883, p. 106; 1884, p. 86; 1885, p. 100; 1886, pp. 148–149;; 1890, pp. 60–61; 1891, p. 244; 1896, pp. 327–328; 1899, p. 161.

(248) *The Washington Forge Mine.*

The Washington Forge mine was on the north side of the Rockaway River, in Rockaway Township, Morris County. It was a few hundred yards northeast of the Orchard mine, from which it is supposed to be separated by a fault with a throw to the right of about 150 feet (see above under Orchard mine).

[1] While this report is in press (Sept., 1910) the newspapers announce the permanent closing of the mine on account of excessive cost of pumping.

The mine was opened in 1868 by two shafts 20 feet apart that revealed an ore body 10 feet wide. By the year 1873 the mine had been developed through a length of 200 feet and to a depth of 150 feet. It was closed about 1875 because of the difficulty of handling the water, but it was reopened in 1879 after the drainage tunnel to the Orchard mine was completed, and was operated until 1881. By this time the property line was reached, and further mining was done through a new shaft a few rods northeast of the older ones, under the name of the West Mt. Pleasant mine. Between the two shafts was a fault with a throw of 10 feet to the right.

The average depth of the workings when the mine was closed in 1881 was 175 feet, although one shaft was down 300 feet.

Between the West Mt. Pleasant mine and the Mt. Pleasant mine to the northeast is an interval of untested ground 700 feet long.

A sample of the ore raised in 1880 from the Washington Forge mine gave:

$Fe = 61.84$; $P = .633$; $S = .245$; $Ti = 0$; $Mn = 0$. Authority: N. J. 1880, p. 107.

Another sample taken from a pile of 50 tons gave:

$Fe = 57.39$; $P = 1.261$. Authority: 10th Census, p. 170.

References: N. J. 1868, p. 578; 1873, p. 44; 1879, p. 55; 1880, p. 107; 10th Census, p. 170; 1883, p. 107.

(249) The Meadow Mine.

The Meadow mine was immediately northeast of the Washington Forge mine, in Rockaway Township, Morris County, on the same vein as the Washington Forge mine.

It was evidently worked before 1884, since in this year the shaft was 400 feet deep and the drifts 300 feet long. It was probably first worked as an independent mine in 1883. Operations continued until 1886, when all work ceased. At this time the mine was 450 feet long. The deposit averaged 4 feet wide, and dipped 57°–60° southeast. There appeared to be neither "bed" nor "cap" rock.

The ore contained a little phosphorus, but practically no sulphur.

The yield of the mine in 1884 was at the rate of 24,000 tons annually. In 1886 it produced about 3,500 tons.

References: N. J. 1884, p. 86; 1885, p. 100; 1886, p. 147.

The Burwell Mine.

The Burwell mine was near the Washington Forge mine, and about one-fourth of a mile distant, in Rockaway Township, Morris County. It was opened before 1855 and abandoned.

Reference: N. J. 1855, p. 206.

(250) The Mount Pleasant Mine.

The Mount Pleasant mine, in Rockaway Township, Morris County, was on the northeast extension of the vein worked by the Washington Forge mine.

It is one of the oldest mines in the State, having been first opened in 1786. In 1868 the extreme length of the workings was about 1,200 feet on one deposit and 800 feet on another. Their depth varied between 140 feet and 225 feet. The mine was worked steadily until 1896, when it was dismantled.

By 1883 the vein had been mined to a distance of 1,800 feet southwest of the highway from Dover to Berkshire Valley and 1,000 feet to the northeast under the swamp. In 1896, when the mine was closed, its length was 3,500 feet and its depth 1,400 feet, measured on the slope.

Up to June, 1880, it is estimated to have yielded 336,000 tons of ore. Most of this ore came from the northeast end of the mine, very little having been obtained from its southwest end. In 1880, however, the southwest portion of the property was explored in connection with the work at the Washington Forge mine and a new shaft was sunk under the name of the West Mount Pleasant mine (see Washington Forge mine, p. 393).

As mining proceeded it was found that there were four veins on the property, as follows: The Northwestern, or Dolan, or

Huff vein, the Main or Teabo vein, a third 66 feet southeast of the Main vein and a fourth 294 feet further southeast. The main vein, which was the principal one worked, averaged about 6 feet in width. There were three shafts on this, and these mined five shoots of ore. Their dip was about 57° southeast, and all pitched northeast. Their average height was 60 feet.

The mine was especially noted for the number of faults that crossed the ore bodies. These were recognized in the early days of the mine's history. Five were cross faults, dipping to the northeast at angles of approximately 75°. At the southwestern-most fault (as in Fig. 22) the throw was 5 feet to the left. Fault

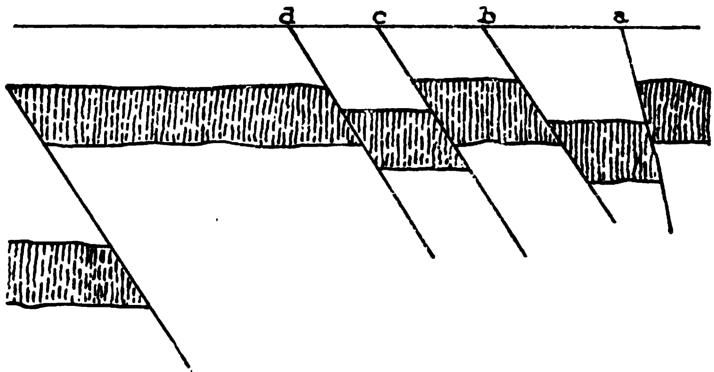


Fig. 22.

Plan of faults at S. W. end of Mt. Pleasant Mine.

No. 2 (b), which was 45 feet further northeast, had a throw of about the same magnitude to the right. At the third fault (c), about 65 feet from No. 2, the throw was 3 feet to the left. At No. 4 fault (d), 35 feet distant from No. 3, the throw was 3 feet to the right, and at the fifth fault, 265 feet from the first one, the displacement was 20 feet to the left. This separated the southwest from the northeast workings. Besides these five faults there was another, which dipped northeast at about 35° and intersected the third and fourth faults enumerated above, displacing their upper ends 12 or 15 feet to the southwest.

In addition to these the ore was cut also by a number of faults that have been described as "cross slides." These are presumably strike faults, that is, faults striking approximately

parallel to the vein, but dipping in an opposite direction (40°–75° northwest). They cross the vein at the pinches in the ore body, and thus tend to emphasize its shootlike character. In all cases observed the downthrow occurred on the foot-wall side of the faults to the extent of from 5 feet to 35 feet.

As mining progressed several additional faults were observed, at which the throw of the ore body was found to be greater than in any of the instances described above, but their exact positions and the magnitudes of their throws are not known. In 1891 a fault in the bottom of the mine threw the ore body to the right, but upon sinking 40 feet it was recovered with its normal thickness. With increasing depth, however, the ore became bunchy, so that it no longer paid to work. At the southwest end of the mine a drift was started at a depth of 600 feet and driven southwestward 800 feet, when another well-developed fault was encountered, that threw the vein to the left a distance of 70 feet. This fault comes to the surface at the base of the hill 1,000 feet east of the highway. On the southwest side of the fault the deposit opened to a width of 15 feet to 20 feet, and this was tested for a distance of 500 feet. It continued to be rich in iron, but the phosphorus in it was so high that the ore had to be sold at a price that was unprofitable. The deposit was supposed to be the same as that of the Orchard mine. Since it could be worked much more cheaply through the Orchard shaft, it was thought best to close down the mine, which was done in 1896.

The ore was a mixture of magnetite, calcite, quartz, chalcopyrite, apatite, siderite, pyrite and zircon. The calcite was in veinlets and incrustations on the walls of fissures in the wall rocks. The siderite was in seams and bunches in quartz, and also formed a matrix cementing masses of granular magnetite and quartz. The apatite often occurred in masses 6 inches in diameter, that were apparently crystals, in an aggregate composed of this mineral, quartz and magnetite. The quartz, besides being found in the wall rocks, occurred also as lenses in the ore, and in these were found "bunches" of chalcopyrite.

Analyses of the ore taken from the various slopes in 1867 give ideas of the quality of the ore at that time. The results are as follows (N. J. 1868, p. 582):

	Fe	P_2O_5
Northeast stopes,	69.2	1.0
Northeast stopes of southwest workings,	64.7	1.1
Middle stopes at northeast fault, southwest workings,	65.5	0.3
Center of deposit, southwest end, southwest workings,	69.6	0.1
Southwest stopes,	67.0	1.6

A sample of 10 carloads mined in 1880 from the northeast working gave:

$Fe = 64.85$; $P = .185$. Authority: 10th Census, p. 171.

The ore of the Teabo vein in 1886 is reported as containing:

$Fe = 66.0$; $P = .196$.

References: N. J. 1855, pp. 201–206; 1868, pp. 578–582; 1873, p. 44; 1879, p. 55; 1880, p. 107; 10th Census, pp. 170–171; 1883, pp. 107–109; 1884, pp. 86–87; 1885, pp. 100–101; 1886, p. 148; 1890, p. 61; 1891, p. 245; 1896, pp. 327–328.

(251) The Baker Mine.

The Baker mine, in Rockaway Township, Morris County (northeast Baker), adjoins the Mt. Pleasant mine on the north.

It was opened in 1866 on two veins of ore 300 feet apart, of which the western one was 7 feet thick and the eastern one 23 feet. In 1868 the mine was producing at the rate of 12,000 tons annually.

It was extensively developed during the next five years, and in 1873 was 325 feet deep and 335 feet long. The extent of the workings in 1872 are shown in Figure 23. In 1873 a new shaft was sunk southwest of the old workings, near the turnpike, east of the Mt. Pleasant mine, on the strike of the southeast vein. A third vein was opened about this time 25 feet west of the "main northwest vein," but it was small in comparison with the other two. The mine was worked continuously until 1877, yielding about 150,000 tons of ore, when the vein pinched out at the bottom. As borings of 100 feet downward in the plane of the dip of the vein failed to disclose a new ore body, the mine was abandoned. It was reopened in 1884 and worked continuously until 1890, and then again closed. In the fall of 1905 the mine was again unwatered, and a small quantity of ore was raised, but

in January of the succeeding year the entire workings collapsed, burying 20,000 tons of ore that was in sight ready for removal. The accident was reported to be due to the robbing of the pillars.

References: N. J. 1868, p. 583; 1873, p. 44–45; 1879, p. 55; 1890, p. 61; Eng. & Min. Journal, Jan. 20, 1906; N. J. 1905, pp. 318–319.

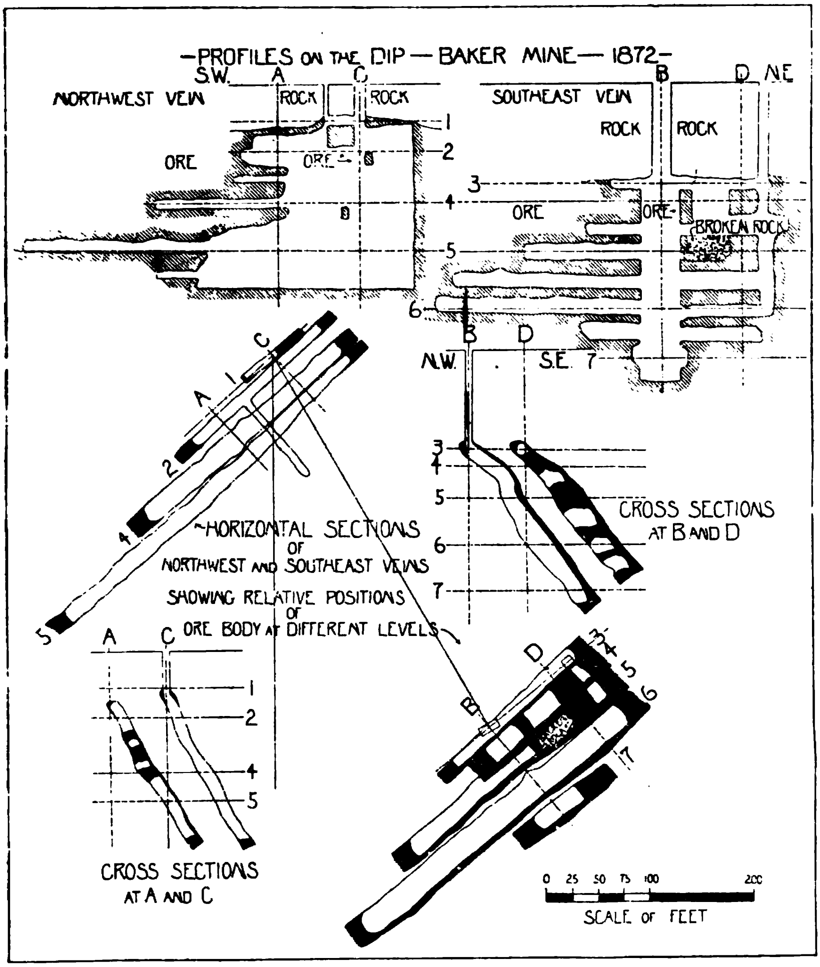


Fig. 23.

Profile and sections of the Baker mine.

(252) The Richard Mine.

The Richard mine is northeast of the Baker mine, in Rockaway Township, Morris County. It is one of the most important mines in the State, and one of the few that are still active.

The mine was first worked before 1856, and it has been in practically constant operation ever since. Between July 1, 1856, and June 30, 1900, its total production was 1,844,769 tons. Since the latter date approximately 1,000,000 tons have been raised, making the total yield to the present time amount to about 3,000,000 tons.

In 1880 ore was being taken through three shafts, of which one (No. 7), 160 feet deep, was the southwesternmost one and was near the Baker mine. The next to the northeast was No. 6, 375 feet deep, and the third (No. 3), which was about 500 feet still further northeast, was 400 feet deep. In 1883 the three shafts that were active were: No. 1, which was to the southwest of No. 7 on the vein that was supposed to be the continuation of the Baker vein. About 1,000 feet northeast of this was shaft No. 2, and 700 feet further northeast was shaft No. 3.

Five veins cross the Richard property. The three to the southeast are continuations of the Baker veins. The next to the northwest was thought to be the continuation of the Mt. Pleasant vein, and the fifth, the northwesternmost, was originally regarded as the Teabo vein.

The southeasternmost vein is the largest. This was opened up for a distance of 2,700 feet, and from it nearly all the ore came in the earlier years of the mine's history. In some of its shoots it was 20 feet wide. In other places it was pinched to 12 inches. Between the two shafts referred to there was a pinch 300 feet long. Both pinches and shoots pitched northeast at low angles (about 15°) and dipped 53° southeast.

During the development of this vein several faults were encountered crossing the ore body. One of these was 524 feet southwest of No. 2 shaft. This had a throw of 40–50 feet to the right, and dipped steeply to the southwest. Another, which was nearly vertical, was found 334 feet northeast of the No. 3 shaft

and 156 feet from the north line of the property. This dipped 85° northeast, and no ore has been found to the north of it, although drifts were cut across the strike of the ore vein north of the fault for a distance of 90 feet southeast and 15 feet northwest.

In 1896, at a depth of 400 feet from the surface and 80 feet east of No. 1 shaft, a 350-foot crosscut into the foot wall rediscovered the vein to the northwest, which was then recognized as the Mt. Pleasant vein. On this a new slope (No. 4) was sunk, which struck the ore at 900 feet, where it was 10 feet wide and dipped 50° southeast. Further exploration made in the foot wall of the old mine between shafts No. 1 and No. 2 proved that the supposed foot wall was only a horse of rock about 2 feet thick, and that beyond this was a deposit of ore 17 feet thick. Three drifts were driven into this (a, b and c in the cross section) and a fourth one (d) which was not completed at the time the plan was made a number of years ago. (Plate IX.).

In 1896 slope No. 3 was abandoned and a new one (No. 5) was sunk 30 feet northwest of the vein and about 450 feet northeast of No. 2, with an inclination of 52°. In 1898 a new deposit was also discovered on the hanging-wall side further northeast. This, however, was thought to terminate abruptly below a bed rock. It was later explored at a further depth of 100 feet, where it was replaced by ore from 3 to 25 feet in thickness. The supposed bed rock was a fold in the foot wall. A summary of the history of the mine is given in the Annual Report of the Survey for 1904, from which the following statements are quoted (page 296–297):

"The Richard Mine contains several shoots of iron-ore, two of which are worked at the present time. No. 1 shoot, now referred to as the 'Mount Pleasant vein,' farthest to the north, is the one from which ore was mined in 1856. * * * Mining from this shoot continued for several years, but was then temporarily abandoned; and No. 2 shoot, now referred to as the 'Richard vein,' lying to the south and overlying the 'Mount Pleasant vein,' was opened. A cross-cut was driven in 1893 at the western end of the property, near No. 1 slope, and connection made between the 'Richard' and 'Mount Pleasant' shoots, which are about 300 feet apart. This cross-cut intersected a shoot of ore about two feet thick, lying between the 'Richard' and 'Mount Pleasant' shoots, which is referred to as the 'Middle vein.' The intersection of these shoots was at a depth of 471 feet in length on the incline. As the

depth of the 'Mount Pleasant' shoot of ore had never before been tested on the Thomas Iron Company's property, its development was at once commenced. Mining operations have been carried on ever since from both shoots, with consequent increase of the output. There are three slopes on the 'Richard vein' going down on the foot-wall, known as No. 1 (length, 533 ft.); No. 2 (length 630 ft.), and No. 3 (length, 738 ft.); and two slopes going down on the foot-wall of the 'Mount Pleasant vein,' known as No. 4 (length, 932 ft.), and No. 6 (length, 600 ft.).

"A new slope, known as No. 5, was begun August 1st, 1896, and completed April 30th, 1901, through which ore is now being hoisted from both shoots. The slope has three compartments, and goes down at an angle of 52 degrees into the rock lying between the 'Richard' and 'Mount Pleasant' shoots. At the depth of 570 feet two cross-cuts were driven; one going south 110 feet 6 inches, and intersecting the 'Richard vein' 100 feet below the old working at No. 3 slope; and the other going north 191 feet, and intersecting the 'Mount Pleasant vein.' The slope has a length of 868 feet, equivalent to a vertical depth of 685 feet. The 'Richard vein' at the point of intersection is 18 feet wide between walls. The 'Middle vein' at the point of intersection is 4 feet wide between walls, and lies 65 feet south of the 'Mount Pleasant vein.' * * *

"The total output of the Richard Mine, since its purchase by the Thomas Iron Company in 1856, up to February 28th, 1904, was 2,212,833 tons, being an average of 46,000 tons per year. The average output during the first eight years was 11,683 tons per year; while the average output during the last eight years was 101,939 tons per year. The output for 1902 equaled the aggregate for the first ten years.

* * * * * * * * * * * * * *

"The ore from the Richard Mine is magnetic and of high grade. The average analysis for the past twelve years, representing shipments of over one million tons (every shipment being sampled), was 60.19 per cent. metallic iron. The highest yearly average was 61.89 per cent., and the lowest 58.54 per cent. The phosphorus averages about 0.75 per cent.; silica, 6 per cent.; lime, 5 per cent.; alumina, 3 per cent."

The rock associated with the ore is largely a very fresh Pochuck gneiss. In this are a few small veins of calcite and seams of a coarse pink feldspathic rock. The wall rock of the vein is a banded gray rock that consists of alternations of Losee and Pochuck gneiss, and between it and the ore are thin selvages of a micaceous dark gneiss. In some of the smaller faults a thin sheet of magnetite fills the fault crack and connects the displaced ends of the ore deposit.

The ore of the Mt. Pleasant vein in the southwest workings was, formerly, not as high grade as that mined on the Mt. Pleasant property. An average analysis showed (in 1896) 56.17 per cent. Fe and 0.85 per cent. P. The ore of the Main, or Richard vein, that was being shipped in 1880, gave:

					Authority.
Sample 4 carloads from No.	7	shaft,	Fe=61.43	P=0.881	10th Census, p. 171
5 " " "	6	"	" 58.05	" 0.851	10th Census, p. 171
5 " " "	3	"	" 62.32	" 0.661	10th Census, p. 171

Recent analyses made by Mr. R. B. Gage, chemist of the Survey, give the following results, which show that the Mt. Pleasant vein at the present time is yielding the better ore.

	Fe	Mn	S	P	SiO_2	TiO_2
Richard vein—						
Average sample, ...	60.18	0.02	0.008	0.672	8.48	1.01
Selected sample, ...	66.17	0.03	0.014	0.825	2.22	0.30
Mt. Pleasant vein—						
Average sample, ...	65.80	0.04	0.011	0.196	3.77	1.30
Selected sample, ...	68.62	0.03	0.012	0.246	1.31	1.29

References: N. J. 1855, p. 201; 1868, p. 583; 1873, p. 45; 1879, p. 55; 1880, p. 107; 10th Census, p. 171; 1883, pp. 109–110; 1884, p. 87; 1885, p. 101; 1886, pp. 149–150; 1890, pp. 61–62; 1891, p. 246; 1896, pp. 328–330; 1897, pp. 320–321; 1898, pp. 234–235; 1899, pp. 152–153; 1900, p. 200; 1901, pp. 141–142; 1902, p. 119; 1903, pp. 103–104; 1904, pp. 296–297; 1905, p. 318; 1906, p. 176.

(253) The Allen Mine.

The Allen Mine in Rockaway Township, Morris County, was another of the important mines during the last century. It was situated immediately north of the Richard mine, its workings being on the supposed northern extension of its eastern vein, but on a distinct lens lying above that exploited at the north end of the Richard mine. The two mines were separated by the fault that has been described as limiting the Richard deposits in the northeast.

The mine was worked before 1855 and continuously from this date until 1882, when active operations ceased. A little exploratory work was done in 1883 and 1884, but nothing new having been discovered the place was abandoned.

The mine was entered by an adit 630 feet long, running at right angles to the course of the vein. From the point where the adit penetrated the ore body work had proceeded 230 feet to the northeast in 1855 and 350 feet to the southwest. The dip of the ore body was 65° southeast and its pitch was comparatively low to the northeast. At the surface it was divided into two parts by

a horse of rock that extended some distance downward. At the junction of the two parts below the horse the thickness of the united veins was 23 feet. This thinned out, however, at both ends to 4 or 5 feet.

The hanging wall of the northeast workings consisted of a curious conglomerate rock composed of nodules of greenish-white feldspar imbedded in a schistose matrix of magnetite, hornblende and biotite. The material winds around the nodules in a way to suggest that the latter were already solid while the matrix was still plastic. Some of the nodules, moreover, are schistose, with a foliation that is not conformable with the foliation of the matrix.

Inspection of the dump shows many fragments of this rock in which the nodules of feldspar are apparently distorted porphyritic crystals of oligoclase. Under the microscope the matrix is seen to be composed of green hornblende, a little green pyroxene and some magnetite. The nodules are oligoclase and epidote. Sometimes this conglomerate is interlayered with a light-colored rock, in which are also occasionally observed large feldspar crystals. Both rocks are apparently igneous. A slight crushing of some of the components suggests that the nodular character of the feldspar masses may be due to the rounding of porphyritic crystal by friction. The rock

"contains also large seams of pyrite and numerous fissures and cavities which are lined with quartz crystals mixed with limonite, sometimes with incrustations of a very delicate transparent mammillary opal, sometimes with very handsome rhombohedral crystals of a pure white opaque siderite."

In some places the foot wall contained cavities lined with similar siderite crystals and well-terminated quartz crystals.

Another peculiar feature of the ore deposit at this mine is the presence of large masses of a breccia-like aggregate of angular masses of magnetite cemented together by white siderite. Cavities in the ore are also met with, the walls of which are lined with small rhombohedrons of siderite, with which are associated limonite powder, pyrite crystals and hexagonal plates of an olive-green mica. Veinlets also cross the ore body in various directions. Their walls are lined with coatings of pyrite, while their centers are filled with white siderite. Where the veins swell, bunches of quartz crystals are imbedded in the siderite.

The mine was worked on the supposed Teabo vein of the Mt. Hope mine until 1873, when a tunnel was driven west to strike the Jugular or Mount Hope vein, supposed to be 300 feet further up hill to the west. This was, however, not successful. One vein only has, therefore, been worked, and in this the shoots were found to be larger toward the northeast. The southwest shoots contained a greater proportion of rock intermingled with the ore.

The relation of the veins in the Allen mine to those in the Richard mine are not known certainly, because of the fault between the Richard and Allen properties. It has been assumed that the Allen workings were on the northwest vein of the Richard mine and that the main Richard vein lay further southeast, but the tunnel that was driven into the hill seems to show that the main vein on the Allen property corresponds with the Main, or Richard vein, in the Richard mine. This tunnel cut three veins, the main working vein at 600 feet from its entrance and two other smaller ones—one near the entrance and the other at a distance of 500 feet from it, or at 100 feet east of the main vein. From the end of the tunnel a drift of 385 feet and a bore hole of 100 feet cut 485 feet of rock without finding more ore. Moreover, a boring that was started in the main vein southwest of the tunnel and directed southeast for a distance of 600 feet found no ore. It is possible that the continuation of the Richard shoot, which was large up to the face of the offset, was faulted downward, and that this displacement together with the pitch of the ore has carried it below the workings of the Allen mine. If this is not so, the fault between the Richard and Allen property must throw the Richard vein to the west as it crosses the line between the two properties.

The ore of the Allen mine varied greatly in quality. Only a few analyses have been published and these are old.

In 1880 the vein had pinched to 18 inches and but little ore was being mined. A sample from three carloads gave to the chemists of the 10th Census:

Fe=56.99; P=593. Authority: 10th Census, p. 171.

References: N. J. 1855, pp. 196–200; 1868, pp. 583–587; 1873, p. 45; 1879, pp. 55–56; 1880, p. 107; 10th Census, p. 171; 1883, pp. 110–111; 1884, p. 88; 1885, p. 101; 1886, p. 136; 1899, p. 162.

(254) The Teabo Mine.

The Teabo mine, in Rockaway Township, Morris County, adjoined the Allen mine on the northeast.

It was very extensively worked in the early part of the nineteenth century by a shaft more than 200 feet deep, but it was closed down before 1855 and then reopened a year or two before 1868. Up to this time but one deposit had been mined, and this was apparently in a vein that lay a few yards west of that which supplied the ore at the Allen mine. The mine was worked steadily until 1886 through two shafts that were connected underground. One of these (No. 2) is reported to have been 460 feet deep in 1880 and the other (No. 3) 355 feet in depth. A third shaft (No. 1) southwest of No. 2 was not in use at that time. The mine yielded about 22,500 tons of ore during the census year. In 1891 it was abandoned.

A new shaft (No. 4) was sunk in 1902 a considerable distance from the old shafts. This was then driven to a depth of 240 feet and in its bottom was found a vein of 50 per cent. ore 6 feet wide. At 60 feet from the surface a smaller vein had been cut. During this year about 1,000 tons of ore were raised. Work was again suspended in 1903 because of the slack ore market, but explorations were resumed in 1905, and continued through the suceeeding two years. A 2-foot vein of rich ore was struck in the hanging wall on the 800-foot level at a distance of 27 feet from the shaft and a somewhat thicker vein 40 feet from the shaft in the foot wall. The shaft was then sunk 40 feet farther and crosscutting was again begun. Unfortunately, however, one of the crosscuts entered old workings, the presence of which were unsuspected, and the shaft was abandoned in 1907. In the meanwhile a drill hole located 100 feet northwest of the shaft was put down at an angle of 70° to the northwest to a depth of 138 feet, where it stuck and was therefore abandoned. It found no ore. A second hole begun 40 feet east of this one went down 276 feet and encountered 1 foot of ore analyzing 59 per cent. of iron and 0.017 per cent. of phosphorus.

The total yield of the Teabo mine is not known. Between January, 1871, and January, 1879, however, it produced 144,766

tons, and in the immediately succeeding years about 20,000 tons annually.

The principal mining, as has been stated, was on a vein that was supposed to correspond very nearly with the main vein at the Allen and the Richard mines. This, in the Teabo mine, was known as the Teabo vein. It comprised the usual shoots and pinches characteristic of the district. There were at least three shoots, each about 45 feet high, and all dipping 70° southeast and pitching about 21° northeast on the bed rock. The top shoot averaged 5 feet in width. The middle shoot averaged 16 feet and the lower one 18 feet. The rock between the shoots varied between 40 feet and 60 feet in height.

All attempts to find the Taylor vein of the Mt. Hope mine were futile. The original works were on the Brannin vein, which had been opened very early near the Mt. Hope line. Later this vein was abandoned, and all the operations were concentrated on the Teabo vein, which is the one referred to in the preceding paragraph.

The ore was of two varieties. Some of it was finely granular and had a jointed structure and a purplish tinge. Other specimens were coarsely granular and contained considerable quartz and mica.

Partial analyses of the ore raised in 1868 are as follows:

	Fe_3O_4	S	P_2O_5	SiO_2 and ins.	Fe	Authority
1—	88.4	0.0	0.3	11.8	64.0	N. J. 1868, p. 568
2—	75.4	0.0	1.3	13.7	54.6	N. J. 1868, p. 568

1. Sample from depth of 200 feet next to foot wall.
2. Sample from depth of 200 feet next to hanging wall.

More complete analyses of two samples published in 1876 gave:

	Fe_3O_4	Mn_3O_4	Al_2O_3	CaO	MgO	S	P_2O_5	SiO_2	Total
No. 1—	69.25	0.26	4.48	3.40	1.98	.102	1.62	17.77	= 98.862
No. 2—	71.81	0.18	4.02	2.22	2.34	0.01	1.06	17.21	= 98.85

A sample taken by the agents of the 10th Census from a shipment of twelve carloads yielded:

Fe=59.31; P=0.468. Authority: 10th Census, p. 171.

References: 1855, pp. 195–196; 1868, pp. 587–588; 1873, p. 45; 1879, p. 36; 1880, p. 107; 10th Census, p. 171; 1883, p. 111; 1884, p. 88; 1885, p. 101; 1886, pp. 151–152; 1890, p. 62; 1891, p. 246; 1901, p. 142; 1902, p. 120; 1903, p. 104; 1904, p. 298; 1906, p. 176; 1907, p. 172.

(255) *The Mount Hope, Back Vein.*

The Mount Hope, Back vein, was about one-fourth of a mile northwest of the main Mt. Hope veins, on the top of Mount Hope hill. In situation it appears to occupy the same position with respect to the Mount Hope veins as the Huff does to the Mt. Pleasant vein. It was opened up before 1868, but was never worked to any considerable extent.

Reference: N. J. 1868, p. 597.

(256) *The Mount Hope Mines.*

The Mount Hope group of mines, in Rockaway Township, Morris County, is northeast of the Teabo mine. These mines constitute one of the most valuable mining plants in the State, and have contributed a large quantity of ore to its tonnage. The deposits have furnished ore for over 125 years, and are still actively being worked.

The Mount Hope mines originally comprised openings in nine ore bodies, of which four were on Mount Hope, three on Hickory Hill and two on Mt. Teabo. The oldest workings were the "open work" and the Jugular vein operations in what was known as the Mount Hope Blue mine, which was on the northeast side of Mt. Hope (Fig. 24). The first openings were made before the Revolution, the Mount Hope furnace having been built in 1772. The ore was reached by two inclined planes descending to a depth of 100 feet. These penetrated an ore body with an average thickness of 10 feet and a dip of 68° southeast. The ore was worked down from the surface, producing a great pit, which to the northeast extended underground. In this pit the ore is described as having been "stratified." Its foot wall is covered with furrows possessing a definite inclination to the northeast. This was before 1855.

Later an adit, known as the Big Tunnel, was driven into the hill from the southeast, and the ore was raised to the adit level through shafts. This adit intersected five different veins, as follows (Fig. 25): First, to the southeast, a vein from 2 to 4 feet

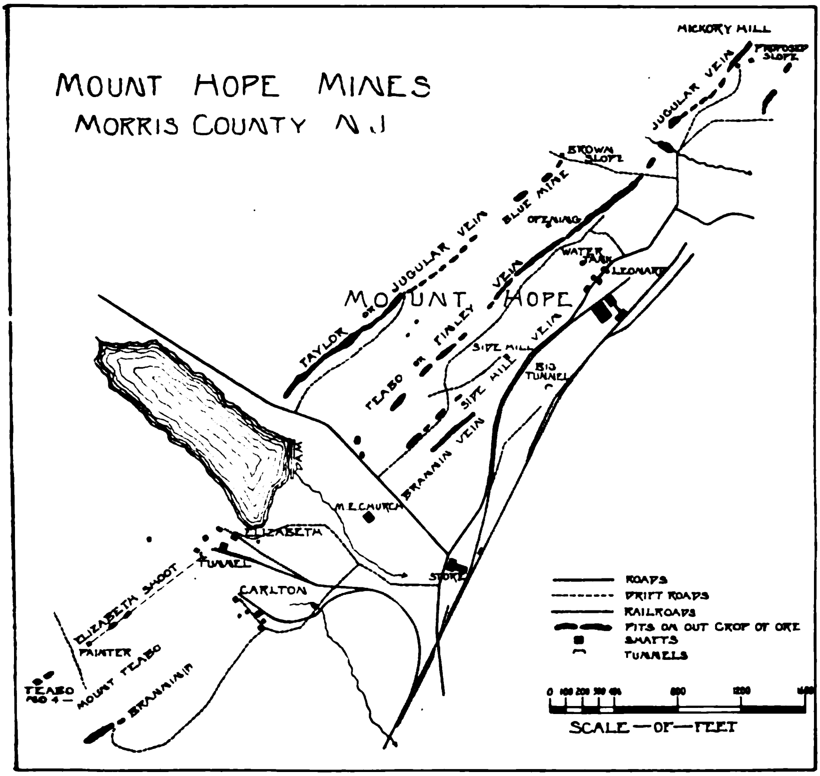


Fig. 24.

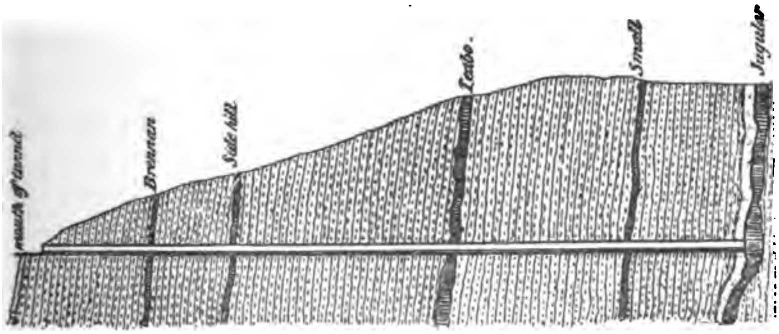


Fig. 25.

Section of ore veins at Mt. Hope Tunnel. Scale, 235 feet to 1 in. (From Geology of New Jersey, 1868, p.594.)

thick, known as the Brannin vein; second, a vein from 3 to 4 feet wide, called the Side Hill vein; third, the Teabo, or, as it was later called, the Finley vein, 5 or 6 feet wide; fourth, a small vein 200 feet northwest of the Teabo or Finley vein; and, finally, the Jugular or Taylor vein. The third, or Teabo vein, was 504 feet from the tunnel entrance. It was so named because it was supposed to be identical with that worked at the Teabo mine, but latterly it has been called the Finley vein.

Before 1868 the Teabo and the Brannin veins had also been opened at a number of places further to the northeast. The latter particularly had been exploited by four or five shafts sunk to depths of 35 or 40 feet. These showed the vein to be exceedingly variable in width. In some places it measured 17 feet across, and in others was pinched to 1 or 2 feet. Some of the shafts sunk upon it had received names, but as they were abandoned after the tunnel was completed, their names soon fell into disuse and were forgotten. Among those best known were the Clay mine, Welch's drift and Gallagher's cut. On the dumps of some of these shafts were found masses of cellular quartz containing limonite, chalcedony, fluorite in veins cutting hornblende-schist and "specimens of black crystalline hornblende containing disseminated apatite," the latter, sometimes in crystals, measuring several inches in their longest dimensions.[1]

The ore of all the veins was cut by veinlets of pyrite sometimes as large as 2 or 3 inches in width, and their wall rocks were traversed by veins of epidote. In the country rock in the neighborhood of the ore bodies were often masses composed of large crystals of apatite, quartz, black mica, hornblende and calcite. They also contained, occasionally, crystals of cupriferous pyrite. In the ore were found also seams of chalcedony and pyrite and nodules of red hematite in an irregular mixture of quartz and feldspar.

The yield from these veins in 1868 was at the rate of 72,000 tons annually.

In addition to the deposits in the veins near the tunnel, two others were also worked very extensively before 1868. These

[1] N. J. 1868, p. 593.

were on the northeast side of Mount Teabo. The one most worked was known as the Elizabeth. It is apparently an ore shoot in the Teabo vein several hundred feet above the shoot worked in the Teabo mine to the southwest. It was from 6 feet to 25 feet wide, dipped 72° southeast and pitched 25° to 35° northeast. The ore body was entered by a tunnel driven 241 feet south passing through a fault of 5 feet. At this distance the deposit "cut out" at the bottom and the bed rock rose gradually to the surface. That portion of the ore body above the tunnel level was worked by three shafts situated to the south, *i. e.*, higher on the hill (see Plate X.).

The third set of deposits is to the northeast on Hickory Hill. They were known as the Hickory Hill mines and are described in another place under this name (see page 416). The deposits are separated from the Mount Hope veins by a fault that intersects the surface near the brook between Hickory Hill and Mount Hope.

Mining on all the veins continued for a number of years with slight interruption, most of the ore being obtained from the Jugular or Taylor, the Teabo or Finley, and the Brannin veins on Mount Hope. The Jugular vein was opened all the way to Hickory Hill, its continuity being broken only by the brook fault where it was displaced 160 feet to the right. In 1874 the Hickory Hill and the Taylor mines were shut down, but the latter was reopened in 1880. The Elizabeth mine was operated without interruption through this period, yielding about 30,000 tons of ore annually. In this same year a little ore was raised from the Brannin vein at Hickory Hill. The aggregate tonnage of the entire group of mines to the end of this year was estimated at 1,000,000.

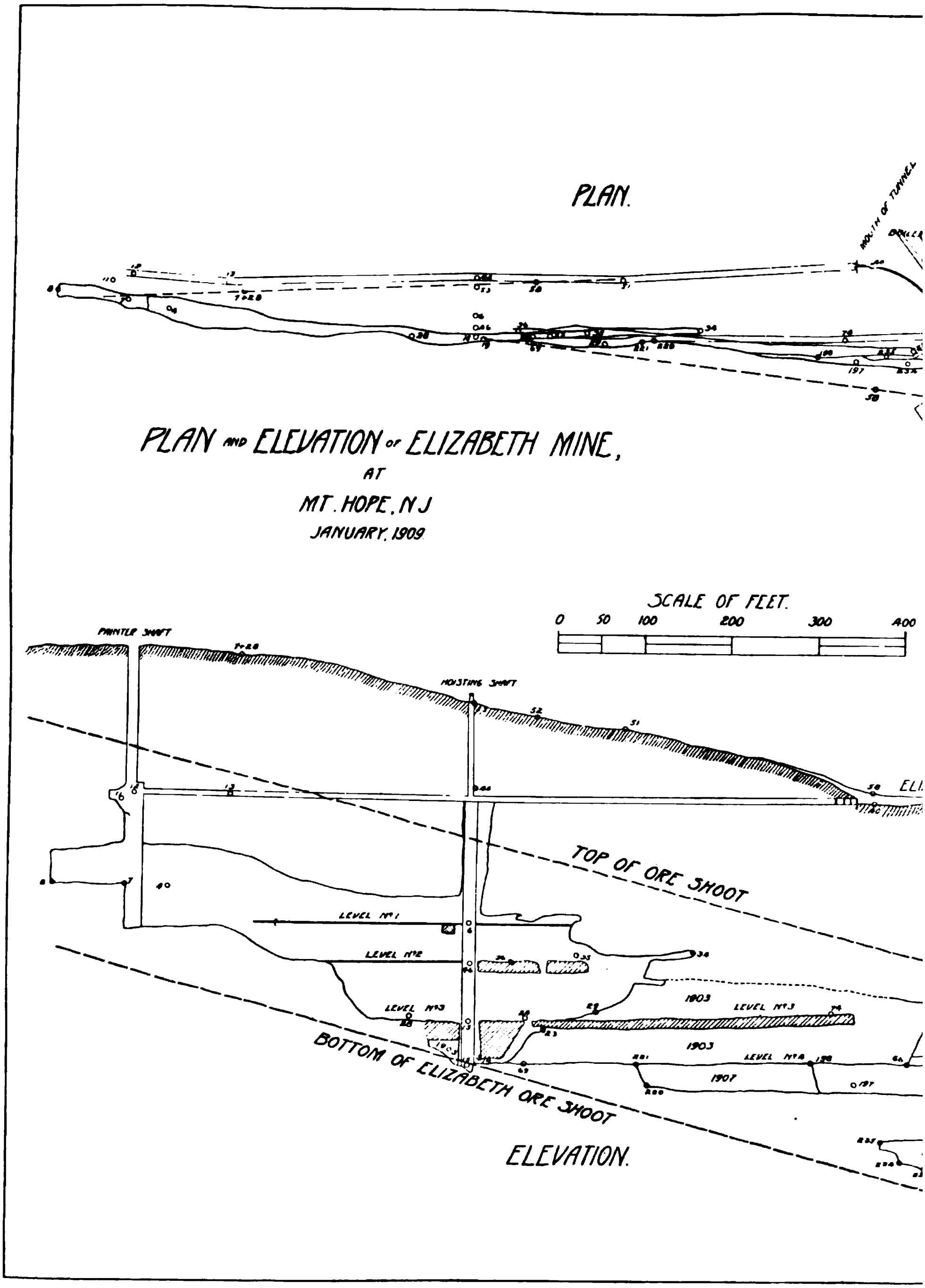
Shortly after 1880 the Elizabeth mine was closed, but work continued on the Taylor (Jugular), the Teabo (Finley), and the Side-Hill veins (see Fig. 24.) In 1883 these three veins were being mined, the former through the Platt shaft, which had reached a depth of 200 feet below the tunnel level. The upper portions of the veins were lean, but the ore in all increased in richness with depth. The Teabo vein was found to maintain its steady northeast trend, but the Side Hill vein was found to

turn slightly to the east. A little to the northeast of the workings the deposit was lost and the vein was not recovered until the brook fault was crossed. Where mined, the Side Hill vein was found to dip to the northwest (Plate XI.) In the higher levels the two veins are supposed to have coalesced, giving rise to a big shoot in which the ore consisted of two bands of different types. At the depth of 330 feet beneath the tunnel, however, the ore was 12 feet wide and had the character of that of the Teabo vein.

In 1883 the Elizabeth mine was again opened but was not actively operated until 1889 or 1890, since which time it has worked continuously except during the period between 1893 and 1899, on an ore shoot that pitched 25° to 30° northeast. Its maximum height was 140 feet, its thickness from 3 to 25 feet, and its dip from 65° to 70° southeast.

The Jugular or Taylor vein exhibited the shoot structure very perfectly. Some of the shoots were 30 feet wide and pitched 30° to 40° northeast. They dipped 70° to 75° southeast. The shoot that was worked in 1886 was separated from another above by a pinch 18 inches thick and was terminated below by another pinch of approximately the same thickness. At no place in the development of this vein did the ore entirely disappear. The ore averaged 60 per cent. of iron, 1.9 per cent. of phosphorus and contained a little sulphur. In the Side Hill vein there was 0.35 per cent. of phosphorus near the surface and 1 per cent. of this substance at the depth of 300 feet.

In 1893 all the mines of the group were closed down and remained idle until 1899, when the Elizabeth mine was reopened and 3,000 tons of ore removed from its southwest end. In the following year 15,000 tons were taken from this mine, practically exhausting the supply as far southwest as the line of the Teabo property. Preparations were made for taking the ore from the northeast end of the vein, and later a new shaft on a 72°–79° slope was sunk a little east of the entrance to the tunnel, which was subsequently abandoned. It reached the ore at something over 200 feet, and in January, 1909, had a vertical depth of about 500 feet (Plate X.).


PLAN.
PLAN AND ELEVATION OF ELIZABETH MINE,
AT
MT. HOPE, N.J
JANUARY, 1909
SCALE OF FEET.
0 50 100 200 300 400
PAINTER SHAFT
HOISTING SHAFT
TOP OF ORE SHOOT
LEVEL Nº1
LEVEL Nº2
LEVEL Nº3
LEVEL Nº4
1903
1907
BOTTOM OF ELIZABETH ORE SHOOT
ELEVATION.

The Taylor mine, on the Jugular vein, was also unwatered in 1899, and 6,000 tons of ore were raised. In the following year a new shaft was sunk further to the northeast at an angle of 68 per cent. to the southeast, as all the ore in the southwest portion of the vein had been removed. This is known as the Brown slope. (Fig. 26.) In the bottom workings of the new shaft about 200 feet northeast of its foot a fault was encountered, which dipped 49° south and crossed the ore body obliquely, so that in the deeper levels of the mine the ore was soon cut out by the intersection of the bottom rock and the fault (see Fig. 26). It was supposed to be a continuation of the brook fault, which at the surface passed between Mt. Hope and Hickory Hill. The mine was abandoned, and is now (1908) full of water.

The Elizabeth mine has been kept at work continuously between 1899 and the present time, and the Taylor mine was operated from 1890 to about 1903, all the mining on the Taylor vein being done since 1901 through the Brown shaft. In 1906 a new shaft, known as the Leonard, was opened to mine ore from the Side Hill vein, but no ore was raised through it until 1907 (Plate XI). In this same year a magnetic concentrator was built near the Leonard shaft, and in the following year it was placed in commission. All the ore from the Elizabeth, Leonard and the Carlton shafts (see below) is passed through the plant, thus enabling the operators to dispense with the necessity of hand-cobbing, which in the case of the Carlton ore would be very expensive, as the material from this mine is on the whole rather lean.

Explorations were made by diamond drilling in 1903 and 1904, holes being put into both the hanging and foot of the Elizabeth vein in the search for the southwestern continuation of the Mount Hope veins. Nothing was found within a distance of 504 feet to the northwest of the main vein, which is supposed to be the Teabo, or Finley, vein of the Mt. Hope workings; but on its southeast side a small vein was encountered at a distance of about 430 feet south of the hanging-wall of the main vein. One of the holes drilled in this direction was over 700 feet long, but no ore save this small vein—about 6 feet wide—was discovered. This was further explored in succeeding years, with the result

that in 1907 a new shaft—the Carlton—was sunk upon it due south of the Elizabeth shaft (see Fig. 24 and Plate XI.) The

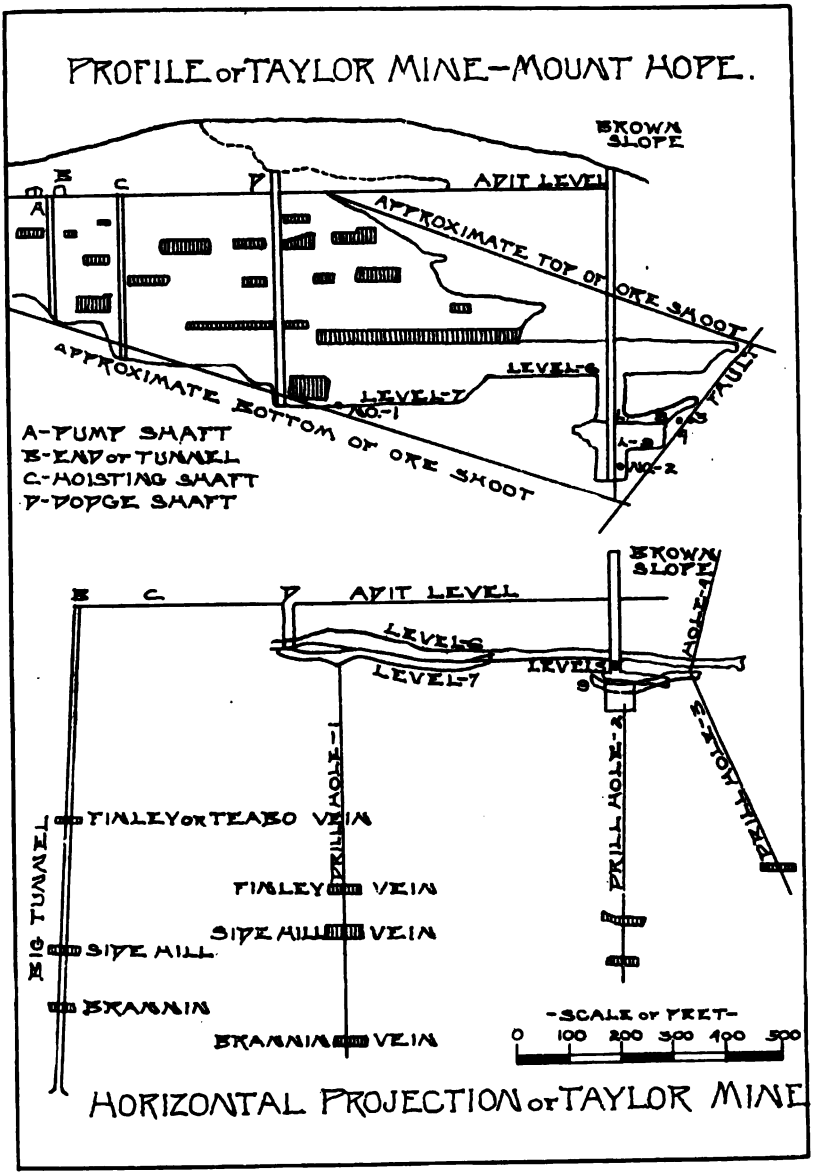


Fig. 26.

new vein thus explored is supposed to correspond to the Brannin vein in the tunnel mines, though its ore is much leaner than in other portions of the vein. Explorations were also made by drilling to the southeast of the lower levels of the Brown shaft of the Taylor mine. These revealed the presence of the Finley, Side Hill and Brannin veins at distances of 400 feet, 475 feet and 675 feet southeast of the Taylor vein (Fig. 26).

In the vicinity of the Mount Hope mines there are, besides the veins above mentioned, two others that are entirely independent of those mined. One, 3 feet thick, is a vein of lean ore situated between Mt. Hope and the White Meadow mines. The second was found west of the Jugular or Taylor vein, on the line of strike of the Huff vein (see Mt. Hope, Back vein, p. 408). The ore in the latter was, however, high in titanium, and consequently the deposit was never developed.

All the ore of the Mt. Hope veins contains considerable hornblende and biotite. The Elizabeth ore is coarsely granular and has a blue-black color, while that of the Teabo vein at Mt. Hope has a purplish color.

Analyses of samples taken from the several veins were made by the chemists of the 10th census. Their results are given below (10th census, p. 171-2):

	Fe	*P*
Sample from 8 carloads from Jugular or Taylor vein, ...	58.77	1.1777
Sample from 14 carloads from Elizabeth vein, ...	57.67	0.971
Sample across stope, Teabo vein, Elizabeth mine, ...	60.61	0.577
Sample from 2 carloads from Brannin vein, on Hickory Hill,	60.81	1.230

A sample of the ore mined from the southwest end of the Elizabeth mine in 1899 gave:

Fe	*SiO_2*	*CaO*	*MgO*	*Mn*	*S*	*Al_2O_3*	*Authority*
61.82	6.70	1.60	tr	tr	tr	1.50	N. J. 1899, p. 154

An analysis of an average sample of the shipments from Mt. Hope in 1905 showed:

Fe	*P*	*S*	*Mn*	*Al_2O_3*	*CaO*	*MgO*	*Authority*
63.00	4.70	tr	0.0	1.70	3.0	1.10	Empire Steel & Iron Co.

Recent analyses of the ore from the Elizabeth and Leonard mines, made by Mr. R. B. Gage, and others, furnished by the Empire Steel and Iron Company, of the ore from these two mines and the Carlton mine are as follows:

	Fe	Mn	P	S	SiO_2	Al_2O_3	CaO	MgO
Leonard mine—								
Av. sample (Gage), ..	58.98	0.03	1.065	0.021	7.62			
Av. sample (E. S. & I. Co.), ...	60.003		0.920	0.030	7.000	1.088	3.300	1.086
Selected sample (Gage),	65.74	0.02	0.236	0.021	3.56			
Elizabeth mine—								
Av. sample (Gage), ..	60.96	0.03	0.426	0.008	8.46			
Av. sample (E. S. & I. Co.), ...	60.431		0.492	0.042	7.800	1.292	1.700	.470
Selected sample (Gage),	69.26	0.02	0.214	0.013	1.38			
Carlton mine—								
Av. sample (E. S. & I. Co.), ...	55.820		.760	.042	11.800	1.046	3.200	1.080

References: N. J. 1855, pp. 186–193; 1868, pp. 588–595; 1873, pp. 45–46; 1879, p. 56; 1880, p. 107; 10th Census, pp. 171–172; 1883, pp. 112–113; 1884, p. 88; 1885, p. 102; 1886, p. 147; 1890, pp. 62–63; 1891, pp. 246–7; 1896, p. 330; 1899, p. 154; 1900, p. 201; 1901, pp. 142–143; 1902, p. 120; 1903, p. 104; 1904, p. 298; 1905, p. 317; 1906, p. 176.

(257) The Hickory Hill Mines.

The Hickory Hill mines, in Rockaway Township, Morris County, were on the Mount Hope property, just northeast of the Mount Hope mines proper, and separated from them by a great fault, which has thrown the Hickory Hill veins a little over 160 feet southeast of the line of the Mount Hope veins. The outcropping of the fault is about along the course of the little brook in the valley between the two hills (see Fig. 24).

The Hickory Hill veins have been less extensively worked than those at Mount Hope. Those that have been opened up showed an average thickness of 3 feet and a dip of 65° southeast. Two mines were located on them, which were known as the Hickory Hill North Drift (the Taylor vein) and the Hickory Hill South Drift (Finley vein?). They were operated to a slight extent before 1855, but whether they were worked in 1868 or not is not known. At all events, one of the drifts was in operation in 1873 and had reached a depth of 270 feet. East of the working veins, which, as has been stated, were extensions of those at Mount Hope, two additional ones were opened up by explorations, but they were not worked.

The Hickory Hill mines were shut down in 1874, but a little ore was taken from the Brannin vein, on Hickory Hill, in 1880. An analysis of a sample of two carloads of this ore gave:

$Fe = 60.81$; $P = 1.230$. Authority: 10th Census, p. 171.

An old shaft on the Teabo vein near the south base of the hill was reopened in 1886, and ore was found with a width of 10 feet. The rocks on the west side of the magnetite-bearing beds on the southeast slope of the hill dip 80° northwest, and enclose a few thin beds of ore. These are now being explored by diamond drilling.

References: N. J. 1855; pp. 193–195; 1868, p. 595; 1873, p. 46; 1879, p. 56; 10th Census, p. 172; 1886, p. 147.

(258) The Cogill, or Cogswell, Mine.

The Cogill, or Cogswell, mine, in Rockaway Township, Morris County, was merely an exploration, situated a mile northwest of the Hibernia mines, and about three-fourths of a mile southeast of the east end of Denmark Pond.

As early as 1868 searches were made here for ore, and a shaft was sunk 70 feet deep. Nothing of importance was found, however, although there is a line of attraction in the vicinity of the mine hole. At the present time there are three shafts in this vicinity, one near the road running along the east side of the west branch of Hibernia Brook, and the other two a few hundred yards further northeast on the west slope of the hill between the two branches of the stream. At the latter point is an open cut 200 feet long and 5 feet wide on a vein dipping 75°–80° southeast. Evidently a large amount of work has been done here since 1868, but at what time it was done and with what practical result is not known.

Reference: N. J. 1868, p. 595.

(259) The Greenville Mine.

The Greenville mine was near Marcella, on the south side of the road, between Split Rock Pond and Green Pond, in Rockaway Township, Morris county.

The mine was opened in 1872 and a little ore was shipped. It has not been worked since. The ore body is said to have had a width of 4 feet where struck. At present the site of the mine cannot be discerned.

References: N. J. 1873, p. 48; 1879, p. 58; 1880, p. 108; 1884, p. 88; 1890, p. 102.

(260) The Charlottesburg Mine.

The Charlottesburg mine, in Rockaway Township, Morris County, comprises a series of open pits and shafts on both sides of the road, between Charlottesburg and Split Rock Pond, on the south side of Pequannock River.

The first openings were made in the latter half of the 18th century on a strong belt of attraction about 100 feet wide and several hundred feet long, between Timber Brook and the pond. The exact date of the openings is not known, but it is stated that the furnace and forge at this place were built about 1765. Other openings were made later on the slope of the hill, on the east side of the road to Split Rock, and the mine was worked intermittently until after the construction of the New Jersey Midland Railroad, now the Morris County Railroad, and thereafter practically constantly until 1874, when it was closed, having yielded in 1873 about 30,000 tons of ore. A still later exploration was made to the east of the old mine holes, and two new veins were discovered. The place was again opened in 1880 and operated until 1884 on the eastern veins. In this eastern area there appears to have been five parallel shoots of ore within a breadth of 200 feet, all striking and pitching northeast. Three of these were worked. The mine was again opened in 1886 and was closed in 1888 permanently.

The character and distribution of the ore in the old mine is not known. On the eastern veins there were several shafts. The principal shoot, worked by the southwestern shaft, was 40 feet wide in places, but to the northeast it narrowed to 12 feet. The dip was about 75° southeast, and the pitch low to the northeast. The shoot next to this one on the southeast or hanging-wall side was not so large, but it also was worked to a depth of 200 feet.

On its foot-wall side the ore was very rich. All the ore bodies are reported to have been cut off by a fault at the south end of the pond.

Analyses of the ore of the old mine reported in 1868 were:

	Fe_3O_4	SiO_2 and ins.	P_2O_5	S	Authority
No. 1—	91.0	6.9	tr	tr	N. J. 1868, p. 596
No. 2—	73.4	23.2	0	0	N. J. 1868, p. 596

No. 1—Old opening, west side of road.
No. 2—Later openings, side hill, east side of road.

The ore of the eastern veins discovered in 1874 was fairly rich. It contained much mica and hard, dark "serpentine." Its composition was:

	1	2	3	4	
Fe, ...	61.42	61.47	67.42	64.94	N. J. 1878, p. 98
S, ...	0.274	3.36	0.55	0.39	N. J. 1878, p. 98
P, ...	0.021	0.028	0.014	tr	N. J. 1878, p. 98
TiO_2, ...				1.00	

1. Ore from large opening on vein 9 feet wide. (N. J. 1878, p. 98.)
2. From smaller opening made in 1877 or 1878. (N. J. 1878, p. 98.)
3. From point where vein was 8 feet wide. (N. J. 1878, p. 98.)
4. Black, compact, lamellar ore from hill, east of old mine. (N. J. 1878, p. 98.)

A sample from a pile of 30 tons mined in 1880 gave:

$Fe = 58.15$; $P = 0.151$; Authority: 10th Census, p. 174.

References: N. J. 1840, p. 27; 1868, p. 596; 1873, p. 49; 1878, p. 98; 1879, p. 60; 1880, p. 108; 10th Census, p. 174; 1883, p. 115; 1884, p. 90; 1886, p. 139; 1890, p. 103; Trans. A. Inst. M. E., Vol. 14, p. 905.

(255) The George Explorations.

The George explorations are described as being about one-half the way between Ringwood and Greenwood Lake, in Pompton Township, Passaic County.

Several pits put down about 1875 seem to indicate the presence of a continuous vein 4 feet to 6 feet wide. A partial analysis of the ore showed the presence of only 0.058 per cent. phosphorus, and no sulphur.

Nothing further is known about the place. It may be the same as that described below as the Patterson mine.

Reference: N. J. 1875, p. 34-35.

(261) *The Patterson Mine.*

The Patterson mine is about 1.5 miles northeast of Hewitt, in a little depression between two hills. Several holes were dug some time ago and a shaft was put down about 1903.

The one consists of magnetitic pegmatite with small ore streaks running through it. Ore veinlets also penetrate the country rock in the vicinity of the pegmatite. No ore has been shipped.

MINES IN OLD FURNACE BELT.

The Old Furnace belt of mines extends from a point about one-half of a mile west of Annandale northeast to a point north of Split Rock Pond. It is midway between the important Mine Hill and Chester belts. Only a few openings have been made on it, and only a very few of these have shipped any ore. Most of the explorations are on its southwest end, near High Bridge. Between this point and the Wood mine, north of Split Rock Pond, there is an interval of 30 miles which, so far as is known, has not been explored.

(262) *Sharps Mine.*

The Sharp or Cregar mine, in High Bridge Township, Hunterdon County, was about 1.5 miles east of High Bridge, on the east side of the road to Lebanon.

The mine was opened about 1871 and worked until 1873, and from that time intermittently until 1879. There was one shaft 50 feet deep and several pits. The ore is reported to have been good, but the large quantity of water encountered made mining expensive. The mine was reopened in 1880 under the name of the Cregar mine, and from 200 to 300 tons of ore were raised.

References: N. J. 1879, p. 45; 1880, p. 102.

(263) *The Emery Farm Exploration.*

The Emery, or Emory Farm, explorations were a little more than a mile east of High Bridge, in High Bridge Township,

Hunterdon County, on the south side of the road to New Germantown.

Two openings were made 200 feet apart in a northeast line. In the northern opening, which was 25 feet deep, a vein 2 feet thick was struck, and from it 200 tons of ore were shipped. The ore contained pyrite and hornblende. The southern opening was shallow. From it a very lean ore was obtained, which was practically a garnetiferous rock containing magnetite.

The last work done was in the autumn of 1878, since which time the mine has lain idle. The later explorations are sometimes known as the Van Syckle mine.

Reference: N. J. 1879, p. 45.

(264) The Old Furnace Mine.

The Old Furnace mine was near Beaver Brook, about 2 miles east of High Bridge, in High Bridge Township, Hunterdon County. The openings are on the east slope of a wooded hill, on the west side of the road from Califon to Annandale.

A great deal of work was done in the vicinity about the time of the Revolution and considerable ore was raised for use in the neighboring furnaces. The place was, however, abandoned, and lay idle for many years, until it was reopened in 1869, at a different point by a shaft 80 feet deep and several drifts.

The vein opened up by the new exploration was discovered to be very wide. On the hanging wall was a layer of rich ore that in some places widened to 3 feet. It contained a large percentage of sulphur. The mine was worked for several years. It was closed in 1874 and not reopened again until 1880, when 2,000 tons of ore were raised. At a depth of 150 feet the vein is described as being narrow.

References: N. J. 1873, p. 29; 1879, p. 45; 1880, p. 102; 10th Census, p. 164.

(265) The Sigler Mine.

The Sigler mine was in Rockaway Township, Morris County, a short distance northwest of the Swedes mine.

The vein was only 2 feet wide, but the ore was of excellent quality. It had been worked down 60 feet in 1869, but was not then in operation, nor has it been worked since that time.

The Sigler mine is probably identical with that designated as the Lindsley mine in the old county atlas. It is about three-fourths of a mile northwest of the Swedes mine, near the road between Dover and Mount Hope.

References: N. J. 1868, p. 559; 1873, p. 47; 1879, p. 56.

(266) The Wood Mine.

The Wood mine is the name given to the openings made about 1873 in search of the northern extension of the mineral belt developed at the Split Rock Pond mine. The openings in question are on both sides of the road from Split Rock Pond to Charlottesburg, about 2 miles north of the north end of Split Rock Pond, in Rockaway Township, Morris County.

At this time it was discovered that the ore "vein" ran north from Split Rock Pond at least a mile or so. In 1883 the locality was again explored, and at a point about 2 miles south of Charlottesburg on the road to Split Rock Pond a great deal of work was done, resulting in the shipment of a small quantity of ore. Nothing has been done since, and the place is now abandoned.

References: N. J. 1874, p. 23; 1883, p. 118–119; 1884, p. 91.

The Wrightneour Mine.

The Wrightneour mine was west of Monks Station, on the Greenwood Lake branch of the Erie Railroad, in Pompton Township, Passaic County. Its exact location is not known. It may have been the same as the Monks mine (page 423), or at any rate was very near it, and may possibly be the mine described as the Vincent mine.

The place was originally worked as the Henderson mine and abandoned. It was reopened in 1880 by a shaft 50 feet deep and a drift 40 feet long on a vein 4 feet wide. The ore is reported

to have been rich and free from sulphur, but it contained too much phosphorus for Bessemer pig. After some prospecting the mine was abandoned.

References: N. J. 1881, p. 36; 1883, p. 120.

(267) The Monks Mine.

The Monks mine was on the north side of Wanaque River, about two miles above Boardville, in Pompton Township, Passaic County. Its exact position is not known, unless it was a part of the mine known locally as the Vincent mine, in which case the statements made below are certainly in error, as the Vincent mine produced a large quantity of ore, if one may judge from the size of its dumps. No reference to the Vincent mine has been found anywhere in the literature.

The ore contained a little pyrite, but otherwise was free from impurities. The vein was 7 feet wide, but its length was not determined. No mining was ever attempted, so far as is known.

References: N. J. 1873, p. 52; 1879, p. 61.

THE HIBERNIA BELT.

This belt is the longest and most continuous in the State. It contains also the most productive deposit now being worked and the greatest number of mines that have shipped ore in the past, but which are now idle. Many of these mines were large ones, and many of them remained active for a comparatively long period.

The belt extends from Annandale to the State line, about a mile west of Ringwood, a distance of 50 miles. The two ends of the belt have not developed important shipping mines. Its productive portion is the stretch of 19 miles extending from Hacklebarney on the south to Hibernia on the north, marked by about thirty openings, of which the majority have at one time or another yielded ore in commercial quantity. That portion of the belt included within the limits of the Hibernia property has to its credit a larger production than an equal portion of any other belt in the State.

Near Chester the belt is double. It consists of two parallel ranges about one-fourth of a mile apart, and on each is a number of openings that were important about 1880. The ore is fairly rich, but it contains a considerable proportion of phosphorus. Titanium is low.

(268) The Annandale Mine.

The Annandale mine was 1 mile northwest of Annandale, on the south side of the road, between High Bridge and Lebanon, in Highbridge Township, Hunterdon County.

The mine was opened in 1880 on a vein 7 feet wide. About 625 tons of ore were raised from a shaft 30 feet deep, after which the mine was abandoned. The ore was reported to be fairly rich and low in phosphorus.

References: N. J. 1880, p. 102; 10th Census, p. 164.

(269) The Cokesbury Mine.

The Cokesbury, or Cokesburg, mine, was a short distance east of the village of Cokesburg, or Cokesbury, in Tewksbury Township, Hunterdon County.

The mine was worked before the Revolution and closed down some years later. It was again opened in 1863, and abandoned after a short period of activity. It was again reopened in 1872, but soon thereafter again abandoned.

The ore found by the last exploration was rich and contained very little sulphur, but the vein was so small—from 10 inches to 2 feet wide—and the mine so wet that it soon became unprofitable to mine.

References: N. J. 1873, p. 30; 1879, p. 45.

(270) The Burrill Mine.

The Burrill mine, in Tewksbury Township, Hunterdon County, was about 1.5 miles northeast of Mountainville.

It was opened in 1878 and a few tons of ore were obtained. Nothing is known of the character of the ore or its mode of occurrence.

References: N. J. 1880, p. 102; 1883, p. 84.

(271) *The Sutton Farm Mine.*

The Sutton Farm explorations adjoined the Fox Hill mine on the southwest, in Tewksbury Township, Hunterdon County.

The first opening made here was in 1873. It found some ore. Nothing further was done until 1879, when two more shafts were sunk at a distance of about 100 yards southwest of the principal Fox Hill shaft. The deepest was 22 feet. About 50 tons of ore were shipped during the year. In 1881 work was again resumed and 200 tons were raised from a new shaft situated a few yards southeast of the first ones sunk. The deepest shaft was down only 30 feet when the place was abandoned.

References: N. J. 1873, p. 30; 1879, p. 46; 1883, p. 84.

(272) *The Fox Hill Mine.*

The Fox Hill or Fisher mine was about one-half mile south-southwest of the Fox Hill M. E. church, in Tewksbury Township, Hunterdon County, near the west bank of a tributary of Rockaway River. It was first explored in 1873 by several holes.

In the succeeding year the locality was further explored and a deposit was found which was reported to be large and promising. During the next succeeding years other openings were made, one of which was a shaft which was situated to the west of the first openings. The ore contained pyrite and hornblende. Very little was shipped.

In 1877 a sample taken across the vein, which was reported as being 10–12 feet wide, had the following composition:

Fe_3O_4	*CaO*	*MgO*	SiO_2	TiO_2	*S*	*P*	*Fe*	*Authority*
79.40	2.70	.94	11.90	tr	.59	.04	57.50	N. J. 1877, p. 49

References: N. J. 1873, p. 30; 1874, p. 22; 1877, pp. 49–50; 1879, pp. 45–46.

THE MINES NEAR CHESTER.

The village of Chester was formerly an important mining center, not less than 26 different mines being operated in its immediate vicinity. These were along six distinct lines, which

probably represent as many mineralized zones, each comprising, perhaps, several veins. Most of the lines of mines are short, but one that passes through the village has a length of 13 miles, terminating to the southwest in the Hacklebarney mines and to the northeast in the Swedes mine. Along the direct line joining these two termini, or very close to it on one side or the other, are twenty-eight groups of openings, from which ore has been obtained. They are certainly not all on the same vein, but the several veins are so close together, and so distantly separated from other veins, that they may justly be described as constituting a mineral zone. Only fourteen of these are tributary to Chester, the remaining ones being nearer Ironia.

The mines near Chester, beginning with those on the southeastern range and following with those on more northwesterly ranges in succession, and naming them in order from southwest to northeast, are:

1. The Harden mine.

2. The Child, the Quimby and the Tiger mines.

3. The Langdon, the Pitney, the Gulick, the Woodhull and the Budd mines.

4. An opening southeast of the main Hacklebarney mine, the Skellenger or Samson mine, the Hotel, the Collis and the Swayze mines.

5. The Hacklebarney, the Gulick, the Peach Orchard or Creager, the Cromwell, the Creamer, the Cooper, the Kean, the Squier, the Horton and the Barnes mines.

6. The Hedges and the Dickerson Farm mines.

7. The Topping mine.

The fifth and sixth ranges are on two veins about 1,000 feet apart, each of which seems to be continuous throughout the entire distance explored by the mine pits.

(273) *The Hacklebarney Mines.*

The Hacklebarney mines, in Chester Township, Morris County, comprised a large number of shafts and pits situated along both sides of Black River, about 1.5 miles south of Chester. When active they produced a large annual tonnage.

Ore was first obtained at this place about 150 years ago, from an opening southeast of the later mines. The ore was used in forges situated in the near vicinity. Up to the year 1868 all the ore obtained had been taken from near the surface. It occurred in veinlike masses of red ore, with earth walls. At greater depths the ore became black and hard, and contained so much sulphur that it had to be roasted before it could be used by the forges. The mine is south of the terminal moraine, in the non-glaciated region, where rock disintegration has extended to great depths. Rock and ore have suffered considerable alteration, the former being changed to clay and earth, and the latter to a red mixture of limonite, hematite and magnetite through the partial oxidation of the original magnetite. At the same time the sulphur in the original ore was removed, with the result that the soft mixture of iron oxides near the surface was a non-sulphurous ore, which at greater depths passed gradually into a hard magnetite, containing much sulphur. In early times only the soft red ore was utilized, the hard black ore being left in the mine. The ore that was raised was stamped and washed before it was ready for the forge.

Between 1868 and 1873 extensive explorations were undertaken. These disclosed a series of veins half a mile long. On the southwest side of the river two veins were opened, and these were traced northeast across the river to a series of open cuts on its northeast side, where a third vein was discovered. The western vein was followed 600 feet by an open drift. Its dip was 50°–60° southeast, and its average width was 20 feet.

The mine was worked continuously between 1873 and 1884, during which period five veins were operated upon on the northeast side of the river. In 1884 the production fell off greatly. In this year a roaster was built, and many improvements were made in the mine equipment with a view to more economical working. During 1885 six openings were being operated, of which two were on the hill southwest of the river and the other four on the hill on its northeast side. The mine was closed in 1888, but in the summer of 1890 work was resumed on 12 or 15 small shoots of ore. Mining was continued on a small scale

in 1891. A tunnel was driven west into the hill at the river level which penetrated a deposit 50 feet from its mouth. Small quantities of surface ore were removed during succeeding years, but gradually all operations ceased, and the entire plant was abandoned about 1896. When actively operated the annual production was about 20,000 tons.

It is impossible in the present place to refer to all the openings from which ore was obtained at different times during the mines' history. Reference can be made only to a few, which for one reason or another were more important or more significant than those that remain unmentioned.

In 1880, when the operations were most active, there were 14 or 15 open cuts and pits on the property from which ore had been taken, and 12 or 15 small shoots of ore were known that varied in width from 1 to 12 feet, and in height from 15 feet to 200 feet. The most eastern opening was an old pit about 300 yards southeast of the main mine, near the river. This was active in the early days, but had been abandoned long before the present mine was developed.

Of the many openings on the property three were on the hill on the southwest side of the river. Two of these were open pits 135 feet long, 40 feet wide and 45 feet deep, on the same deposit. They were worked to a width of about 35 feet, of which half was merchantable ore. About 100 feet west of these was a narrow vein from 4 feet to 6 feet wide, that was worked by a shaft 125 feet deep. The average composition of the ore from these three openings is quoted under VIII in the table below. Another pit on the southwest side of the river was at the foot of the hill, near the river bank. This was known as the Coal-house pit. It was 150 feet long, 50 feet deep and about 30 feet wide. The suface ore was soft and had to be washed before shipment, while that beneath was hard and granular. Analyses IX and X represent the quality of these ores.

On the northeast side of the river, opposite the Coal-house pit, two cuts were driven into the hillside. In the larger of these, known as Andrew's cut, the ore was 30 feet wide. The other cut—the "East cut"—was on a smaller vein east of the larger one and parallel with it. The mixed ore from these two pits

had the composition indicated in XI. Further up on the hill, northeast of these two cuts, were the Tunnel and the Foley openings, which were in line with Andrew's cut. The George vein opening was several hundred feet east of these. On the top of the hill it was worked from a shaft. Analysis VII represents the composition of the mixed ore from these three pits.

The dip of the ore bodies on the southwest side of the river was 70° southeast, and their strike was north-northeast, or a little more nearly north than the strike of the veins northeast of the stream. At the river a great fault throws the veins about 200 feet to the right, so that their northeast extension on the opposite side of the river is further to the east. On the hill which rises from the river bank the explorations disclosed a great series of interbanded rock and ore belts, with an average dip of 65° southeast and a pitch of 20°–30° to the northeast. The most persistent vein was known as the Tunnel vein. It is characterized by its uniform thickness of 5 feet to 6 feet and its regular dip of 55° southeast. Between this and the George mine, which is 800 feet to the southeast, a large number of small veins were uncovered and mined by a number of shallow pits. Other openings to the northeast of these discovered still other ore bodies, one of which measured 15 feet across. The George vein itself, where opened by the pit, contained three parallel deposits, pitching 30° northeast. The whole hill appears thus to have been crossed by a great mineralized zone, consisting of many parallel veins. At only one place is this zone known to have been faulted to any considerable extent, although small faults were numerous. The only displacement of any magnitude was at the north end of the westernmost pit, where a vertical fault running perpendicular to the ore beds displaced the vein 30 feet to the right. On the southwest side of the river at least five faults were developed in the workings, all of which possessed throws in the same direction.

None of the workings on either side of the river were very deep, so that the persistency of the ore downward was not determined. In the Coal-house cut, however, a shoot of ore was discovered in 1883 which was unquestionably below the bottom rock of the shoot that was worked previously.

Very little exploration is reported east of the George vein. It is known that other ore veins occur on the hill in addition to those enumerated above, but their positions and extent have not been determined. In 1883 a new ore deposit 5 feet wide was discovered about one-third of a mile southeast of the main group of workings near the river, and this was thought to indicate the presence of a new range, but since no further mention of the discovery has ever been made, it is probable that it was of no great importance.

The ore of most of the veins is rather lean. It contains pyrite and biotite in definite bands, that are interlayered with other bands that are comparatively pure. The biotite is a dark-green variety. It usually occurs in layers one-fourth to one-half inch thick between layers of magnetite one-half of an inch thick and upward.

	Insol.	*Fe*	*S*	*P*	*Ti*	*Authority*
I.	12.20	59.21	3.78	0.08	.0	N. J. 1873, p. 35
II.	23.35	52.03	2.33	0.03	.0	N. J. 1873, p. 36
III.		55.72	3.29	0.032		N. J. 1879, p. 48
IV.		57.46	3.42	0.033		N. J. 1879, p. 48
V.		53.75	3.33	0.036		N. J. 1879, p. 48
VI.		57.68	2.66	0.025		N. J. 1879, p. 48
VII.		46.47	3.52	0.075		10th Census, p. 165
VIII.		47.21	3.29	0.098		10th Census, p. 165
IX.		56.59	3.65	0.025		10th Census, p. 165
X.		48.38	0.53	0.057		10th Census, p. 165
IX.		52.00	3.76	0.048		10th Census, p. 165

I. From open cut on the northeast side of river.
II. From the underground workings near the river.
III. From open cut southwest side of river.
IV. From Andrew's open cut.
V. From Birch tree openings.
VI. From Wiggins open cut.
VII. Average ore from Tunnel, Foley & George openings, northeast side of river.
VIII. Average sample from 500 tons of ore from the openings on southwest side of river.
IX. Sample from 75 tons hard ore, Coal-house pit.
X. Sample from 20 tons washed surface ore, Coal-house pit.
XI. Average ore from Andrew's and East cut, northeast side of river.

References: N. J. 1868, p. 557; 1873, pp. 32, 35–36; 1879, pp. 47–49; 1880, p. 104; 10th Census, p. 165; 1883, pp. 87–89; 1884, p. 76; 1885, p. 98; 1886, p. 142; 1890, pp. 66–67; 1891, p. 242; 1896, p. 326; 1901, p. 140.

(274) The Gulick Farm Mines.

The Gulick Farm mines adjoined the Hacklebarney mines on the northeast. They comprised a series of openings along the road from Hacklebarney to Chester, in Chester Township, Morris County.

It is not known when the mines were first opened, but it was some time before 1872, for in this year it is reported that the place was again tested. In 1872 a shaft 60 feet deep was sunk, and through this some of the surface ore was removed. The mine was worked until about 1878, when it was closed. It was probably again opened in 1881, and was operated continuously until 1866. In this year all the shafts that were on the northwest side of the road were abandoned, but another one was sunk on the road, which, at a depth of 20 feet, showed 6 feet of ore dipping 65° southeast. Evidently this shaft was not used long, as no further report of its operation can be found.

The mining developments disclosed the presence of three veins on the property. The eastern one (vein No. 1) was the continuation of the southeast vein at Hacklebarney. It was 12 feet wide. Three shafts were sunk on this. The whole length of the vein that was tested measured 800 feet. A fault, with a throw of 30 feet to the right, was encountered south of the northeast shaft, and at the northeast end of the vein, at a depth of 40 feet, the ore was suddenly replaced by rock, though the vein walls continued undisturbed beyond the ore with a uniform dip of 60° southeast.

The western veins were tested by a number of pits that disclosed a series of small ore shoots. From one of these considerable ore was taken, but most of them remained undeveloped. Near the Hacklebarney property line the line of shoots is faulted 30 feet to the right, and northeast of this fault were two shoots lying side by side.

As at Hacklebarney, the surface ore was soft and red, while that at some depth was hard and black. It contained pyrite, a little green augite and biotite. It was interleaved with thin layers of a green micaceous rock. At the main shaft, which was

a few rods west of the road, the ore varies between 1 foot and 6 feet in width.

An analysis of the ore gave:

Fe = 48.0; *P* = .47; *S* = 1.50; SiO_2 = .19; TiO_2 = 0. Authority: N. J. 1884. p. 76.

The output of the mine from 1881 to 1884 was 9,000 tons.

References: N. J. 1873, p. 36; 1879, p. 49; 1883, pp. 89–90; 1884, p. 76; 1885, p. 98; 1886, p. 142.

(275) The Peach Orchard Mine.

The Peach Orchard or Creagar mine lies northeast of the Gulick mines on the south side of the road, between Hacklebarney and Chester, and about midway between the two villages. The mine formerly consisted of a number of pits, that are now completely filled up.

Several shafts and pits put down about 1870 proved a workable vein, from which considerable ore had been taken before it was abandoned in 1873. It was re-explored in 1883, but with what result is not known.

References: N. J. 1873, pp. 36–37; 1879, p. 49; 1883, p. 90.

(276) The Hedges Mine.

The Hedges mine was in Chester Township, Morris County, about one-half of a mile west of Chester, on the north side of the Chester branch of the Central Railroad of New Jersey, and about one-fourth of a mile north of the Peach Orchard mine. With the Dickerson Farm mine it marks a range west of the main range of Chester mines.

This mine was once a large producer. It was first operated about 1870. The workings consisted of a great open cut 300 feet long and 50 feet deep, and a shaft north of this connected by a drift with the open cut. The ore was in two bodies, 25 feet and 5 feet wide, separated by a rock horse 6 feet wide. The ore mined was nearly all surface material, and was taken out with pick and shovel. It was much mixed with rock, from which it was separated by washing.

At the bottom of the pit the ore was of the usual dark compact variety. Pyrite was quite uniformly distributed through it. Samples obtained during the mining contained 2.45 per cent. S and 0.45 per cent. P.

The mine was worked in 1874 and for a few years thereafter, but was closed down before 1879, after having produced a large quantity of ore, which was used in the manufacture of Bessemer pig.

References: N. J. 1873, p. 37; 1874, p. 23; 1879, p. 49.

The Blauvelt Mine.

The Blauvelt mine was near Chester, in Chester Township, Morris County, probably near the Dickerson Farm mine.

It was opened in 1890 on an old prospect vein, yielding about 2,400 tons.

Reference: N. J. 1890, p. 66.

(277) The Dickerson Farm Mine.

The Dickerson Farm mine was in Chester Township, Morris County, about one-fourth of a mile west of the village, and about the same distance northeast of the Hedges mine, on the same line of attraction.

The mine was opened in about 1870 by two shafts, from which a lean ore was raised. It was worked for a few years and then abandoned in 1872 or 1873. The openings made when the mine was in operation were 80 feet deep. The ore shoots are described as being short.

In 1890 new openings were made on a line of attraction 300 feet long. These uncovered a vein 4 feet wide, from which about 3,000 tons of surface ore were taken. As nothing further has been reported from the project it was probably soon abandoned.

It is not known whether the later openings were near the older ones or not.

References: N. J. 1873, pp. 37–38; 1879, p. 49; 1883, p. 91; 1890, p. 66.

(278) *The Topping Mine.*

The Topping mine was in Chester Township, Morris County It was west of the village of Chester and occupied the territory north of the Dickerson Farm mine.

It was first explored in 1873 on the southeast vein crossing the property. Ore was found and quite a large quantity was mined. The place was temporarily abandoned before 1879, but it was reopened in 1880 and worked for four months, yielding about 875 tons of ore. Explorations were again prosecuted in 1883, but without success.

Both of the Chester ore ranges were opened on the property. The southeastern vein was a continuation of that of the Sampson mine. Several openings on this vein showed the ore to be continuous nearly as far south as the Chester branch of the Central Railroad of New Jersey.

The northwestern vein is 1,100 feet farther to the northwest. Trial shafts dug at intervals on the line of the Dickerson Farm vein and northeast of the Dickerson Farm shaft disclosed a breadth of ore from 5 to 6 feet, running northeast, all the way to the Topping shaft.

The ore was banded with mica and contained some pyrite, thus resembling the Hacklebarney and Gulick ores.

A sample from a pile of 75 tons of unwashed surface ore analyzed in 1880 by the chemists of the 10th census gave:

$Fe = 55.84$; $S = 0.000$; $P = 0.086$; Authority: 10th Census, p. 166.

References: N. J. 1873, pp. 32–33; 1879, p. 46; 1880, p. 103; 10th Census, p. 166; 1883, p. 91.

The Hedges Farm Exploration.

The Hedges Farm explorations were northeast of the Topping mine on the northwest range of ore west of Chester, in Chester Township, Morris County.

Openings made in 1882 and 1883 were not successful in finding a workable quantity of ore.

Reference: N. J. 1883, p. 92.

(279) The Creamer Mine.

The Creamer, or Cramer, mine was northeast of the Topping mine on the northwest vein passing through the Topping property. It was about one-fourth of a mile northwest of Chester, on the road between this village and Chester station, on the Delaware, Lackawanna and Western Railroad.

Ore was first dug here in 1873, but the operations were never more than explorations. So far as known none of the pits reached the solid ore.

References: N. J. 1873, p. 31 and 38; 1879, p. 47; 1883, p. 92.

(280) The Sampson Mine.

The Sampson, Samson, or Skellenger, mine was northeast of the Peach Orchard mine, in the village of Chester, Chester Township, Morris County.

It is the southernmost of the long series of mines on the east Chester vein, which passes from this point northeast through the east side of the Topping property and successively through the Cromwell, Hotel, Swayze, Cooper, Kean, Squier's and other mines still further to the northeast.

The mine was opened in 1867 and worked continuously on surface material until 1873, when it was closed because of the low price of ore. It is not known how long operations were suspended. The mine was idle in 1879, but in 1880 it was reopened. It remained active five years, when it was again closed in the fall of 1885. Up to the year 1880 it had yielded a total of 39,200 tons.

Before 1873 the ore had been removed to a depth of 100 feet from a vein that averaged 5 feet in width. All of it was ore that had the peculiarities of surface material. Later the working entered the hard ore beneath this. By 1883 the mine had reached a depth of 285 feet on the very steep slope of the foot-wall, and a length of 350 feet. The ore was mainly in a single large shoot 350 feet long and 300 feet high, with cap and bottom rocks well developed. Its thickness varied between 3 feet and 8 feet. Be-

low this, however, was a second shoot on which operations were begun before the mine closed down in 1885. The dip of the ore bodies was southeast, but it varied and in places was high to the northwest. Their pitch was 22° northeast.

The ore mined at a depth of 180 feet was a hard, blue magnetite containing pyrite. An average sample taken from a pile of 1,000 tons raised in 1880 gave:

$Fe = 51.39$; $S = 4.158$; $P = 0.097$. Authority: 10th Census, p. 166.

The average analysis of 15,000 tons produced before 1884 was:

$Fe = 53.90$; $S = 3.80$; $P = 0.11$; $SiO_2 = 11.81$; $CaO = 3.00\pm$; $TiO_2 = 0.0$. Authority: N. J. 1884, p. 77.

References: N. J. 1873, p. 33; 1879, p. 46; 1880, p. 103; 10th Census, p. 166; 1883 pp. 91–92; 1884, p. 77; 1885, p. 98.

(281) The Skellenger Mine.

There were two (see page 442) Skellenger mines in the vicinity of Chester. The older one was in Chester Township, Morris County, about 200 feet west of the main street in the village of Chester, in the area later occupied by the Cromwell and Sampson mines.

This mine was first opened in 1867 on an attraction about one-fourth of a mile long. The vein, which had been explored to a depth of 15 or 20 feet in 1868, was said to be 4 feet wide.

Reference: N. J. 1868, p. 557.

(282) The Cromwell Mine.

The Cromwell, or Chester Highland, mine was in the village of Chester, in Chester Township, Morris County. It lay between the Sampson and the Hotel mines, on the Sampson mine shoot, and immediately northeast of this mine.

In 1883 the slope was reported to be 180 feet deep. The mine was therefore probably opened in 1872. It was operated during the greater portion of the years from 1883 to 1886. In the latter year the main shaft was down 210 feet.

On one vein, which was known to be 630 feet long, five shafts were sunk. The width of the deposit varied between 3 and 12 feet, and its dip was 63° southeast. The pitch was 40° northeast. The ore was rich and contained a very little phosphorus. Three shoots were recognized, connected with one another by thin stringers of ore. The ore contained 50 per cent. to 53 per cent. Fe and about 2 per cent. S. About 9,000 tons were raised in 1886.

References: N. J. 1883, p. 92; 1884, p. 78; 1885, p. 98; 1886, p. 139.

(283) The Hotel Mine.

The Hotel mine was north of the Cromwell mine, in Chester Township, Morris County, a short distance north of the road between Chester and Flanders.

Three shafts were put down into the vein between 1870 and 1873, but nothing definite is known as to the character and quantity of the ore found. Since, however, a magnetic line is traceable between this mine, through the Cromwell mine to the Sampson mine, it is probable that the ore is of the same quality in all of these. The locality was never developed into a shipping mine.

References: N. J. 1873, p. 33; 1879, p. 46.

The Collis Farm Exploration.

The Collis Farm exploration was in Chester Township, Morris County, north of the Hotel mine.

The place was first explored in 1873, and 70 tons of washed surface ore were shipped. So far as is known nothing further was done to develop it into a mine.

References: N. J. 1873, p. 33; 1879, p. 46.

(284) The Sweayze Mine.

The Sweayze, or Swayze, mine was three-fourths of a mile north of the village of Chester, in Chester Township, Morris County, on the road between the Hotel and the Cooper mines, probably in the same vein of ore.

The first openings were made in 1870 on a long line of attraction that passes northeast to the Cooper property. This line was tested for 3,000 feet and ore was found at many points. The mine was shipping surface ore in 1873. Shortly after this date it was closed, and was not opened again until 1880. It was again closed in 1883. During 1885 and the early part of 1886 operations were prosecuted on a small scale, but in the latter part of the year work was discontinued.

The vein measured 12 feet to 18 feet in width, but it enclosed in places a horse of rock 3 feet wide. The dip was 45° southeast.

For a depth of 40 feet the ore was weathered to the soft red variety characteristic of this region. Below this depth it was hard and black.

An analysis of average samples mined prior to 1873 gave:

SiO_2	Fe_3O_4	MnO	P_2O_5	TiO_2	SO_3	*Pyrite*	*Fe*	*S*	*P*	*Authority*
11.50	81.79	tr.	0.18	0.0	0.31	3.02	59.21	1.59	0.08	N. J. 1873, p. 34

References: N. J. 1873, pp. 33–34; 1879, p. 47; 1883, p. 92; 1885, p. 99; 1886, p. 151.

(285) *The Cooper Mine.*

The most important of the mines that were known by the above name was about 1 mile north of Chester, in Chester Township, Morris County. It lay between the Sweaze and the Kean mines, and consisted of a number of large open pits and shafts that occupied the northeast extension of the Sweaze vein.

It was opened at the close of 1879 and worked almost continuously until 1885, when operations ceased for lack of ore.

The pits are on a belt of strong attraction. Ore was found in an unbroken line 1,465 feet long, extending from the Sweaze property, which is southwest of the Cooper mine, to a fault which terminates its northeast end by a throw of 40 feet to the right. The plane of this fault dips south, and its strike is oblique to that of the ore vein. The ore in the Cooper vein was from 15 feet to 30 feet thick and dipped 45° southeast. It was soft and red to a depth of 74 feet. A large quantity was obtained by open pits from a series of flat, broad shoots pitching 25° southeast. Later,

when the hard ore was reached, the mining was underground, four slopes being sunk in the foot-wall on an angle of 45° southeast. At one time it was thought a "bottom" rock had been found, but beneath it a deposit of ore supposed to belong in a lower shoot was discovered by drilling. A cross section showing the conditions described is given in figure 27, which is reproduced from the State Report of 1883 (p. 153), with

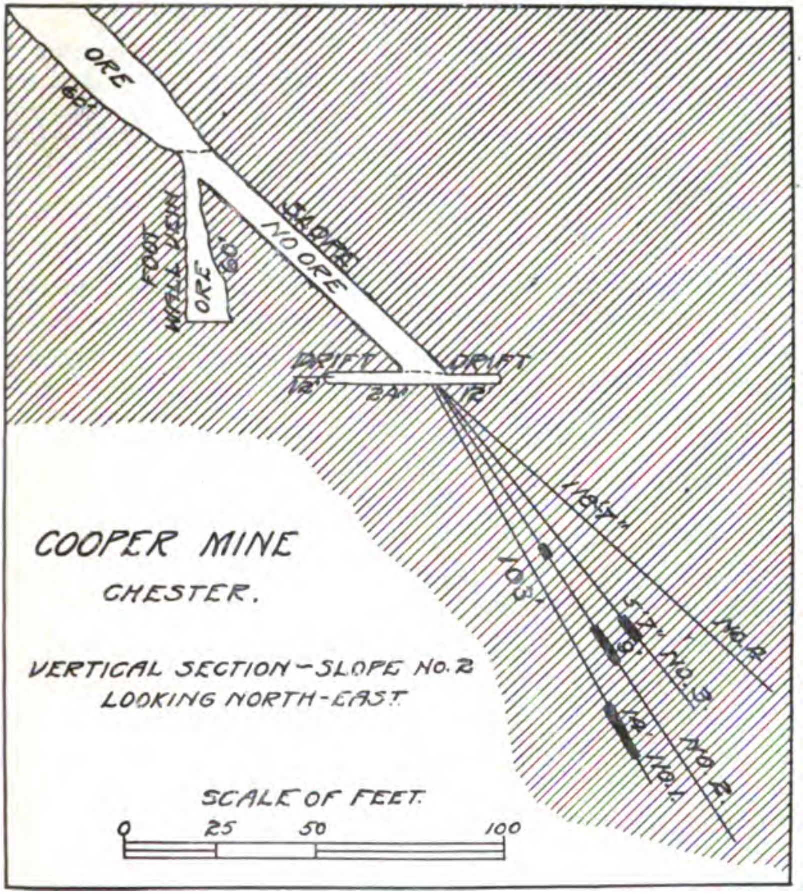


Fig. 27.

Vertical section through Slope No. 2, Cooper Mine, Chester, showing location of drill holes of 1883-1884. (Adapted from diagram in Ann. Report State Geologist, 1883, p. 153.)

modifications based on later information. In 1855 a slope was driven for 120 feet along drill holes Nos. 2 and 3, but only thin strings of ore being discovered, the mine was closed.

The ore was distinctly banded with thin laminæ of mica. At slope No. 3, which was at about the middle of the vein on the property, the ore had a total thickness of 11 feet in two deposits, 9 feet and 2 feet thick, separated by 2 feet of rock. The dip varied between 45° and 65°.

Analyses of surface and deep ore obtained in 1880 gave:

	Fe	*S*	*P*	TiO_2	*Authority*
Red (surface) ore, ...	66.33	0.0	0.078	0.0	N. J. 1880, p. 177
Blue (deep) ore, ...	61.59	4.62	0.047	0,0	N. J. 1880, p. 177
Red (surface) ore, washed,	62.89		0.156	present	10th Census, 166

A later analysis, probably of blue ore, is as follows:

Fe	*S*	*P*	*Authority*
59.91–61.29	3.50	0.066	N. J. 1884, p. 79.

In the three years ending with 1883 the mine shipped 60,000 tons of ore, nearly all of which was surface material. In the following two years about 30,000 tons additional were sent away.

References: N. J. 1879, p. 47; 1880, pp. 103, 122 and 177; 10th Census, p. 166; 1883, pp. 93–94, and 152–153; 1884, p. 79; 1885, p. 99; 1886, p. 140.

(286) *The Kean Mine.*

The Kean mine lies northeast of the Cooper mine, a little over a mile from Chester, in Chester Township, Morris County. It was apparently on the same vein as the Cooper and Sweaze mines.

It occupies about 2,000 feet on the line of the vein passing through the Cooper mine. Near the surface the ore was of the usual red variety, free from sulphur. Deeper, the blue variety was encountered, and this as usual contained a little pyrite. The vein is remarkable for the close crowding of offsets. Six of them within a distance of 54 feet resulted in the throw of the vein 58 feet to the right. At the southeast end another with a throw of 40 feet separated this mine from the Cooper mine.

Reference: N. J. 1883, p. 94.

(287) *The Squier's Mine.*

The Squier's mine was about midway between the Kean and the Skellenger mine, in Chester Township, Morris County, two miles northeast of Chester village.

It was first opened about 1880 on the range containing the Cooper, Kean and other mines further southwest. Although nothing can be learned with reference to the history of the mine, it is evident that considerable work was done on the property, as there can still be seen on the ground evidence of the former existence of five or six shafts.

Reference: N. J. 1880, p. 103.

(288) *The Leake Mine.*

The Leak, or Leake, mine was probably on the extension of the Squier's mine, in Chester Township, Morris County.

It was opened in 1866 on a line of attraction 1,000 feet long, striking north 55° east. The vein was about five to eight feet thick, with a foot of rock through the center. It was probably worked in 1868, but was closed down in the following year. It was reopened in 1882, but was again closed before the end of the season. It had then reached a depth of eighty feet.

The northern workings on the vein were later known as the Skellenger mine.

References: N. J. 1868, p. 558; 1873, p. 38; 1879, p. 49; 1883, p. 94; 1890, p. 94.

(289) *The Beemer Mine.*

The Beemer mine was between the Leake and the Skellenger mines, about 3 miles northeast of Chester, in Chester Township, Morris County.

Two shafts were sunk in 1886, and from them about 2,000 tons of ore were raised. The ore deposit averaged 4.5 feet wide. It dipped 55° southeast and pitched 20° northeast. Several shoots of ore are known to exist in the mine, but none of them have been described.

The ore contained considerable hornblende and mica. Analyses made in 1886-7 by the Durham Iron Works gave:

	Fe	*P*	*S*	*Authority*
Blue ore, ...	41.10	.135	2.958	N. J. 1899, p. 167
Red ore, ...	54.23	.078–.100		N. J. 1899, p. 167

References: N. J. 1886, p. 138; 1899, p. 167.

(*290*) *The Skellenger Mine.*

The Skellenger mine lay about three-fourths of a mile northeast of the Squier mine and about one-half of a mile west of the Daniel Horton mine, and was about midway between Chester and Ironia, in Chester Township, Morris County.

Originally it was a part of the Leake mine property, but later it was worked independently. The mine was operated in 1881 and 1882, but was soon afterwards abandoned.

There were two other Skellenger mines in the Highlands (see pages 436 and 468).

References: N. J. 1868, p. 558; 1883, p. 94.

The Chester Mine.

The Chester mine, or George shaft, was near Horton's station, on the Delaware, Lackawanna & Western Railroad, in Chester Township, Morris County, a short distance east of the Skellenger mine.

The opening was made in 1881 on a small vein of ore dipping southeast. It was followed down about 30 feet, and 400 tons of a sulphurous ore were taken out. The place was then abandoned.

References: N. J. 1881, p. 36; 1883, p. 95.

(*291*) *The Daniel Horton Mine.*

The Daniel Horton mine was about 3 miles northeast of Chester, in Chester Township, Morris County, on the southeast side of the road, between Chester and Ironia, and about one-half of a mile east of the Leake and Skellinger mines.

It was opened in 1867 on a vein 4 to 9 feet thick, and was worked until 1870, when operations ceased, after about 4,000 tons of ore had been raised. The ore body consisted of magnetite containing uniformly distributed through it considerable quartz. It dipped 50° southeast. One of the slopes had reached a depth of 160 feet when mining ceased. At the bottom a roll of the hanging wall cut out most of the ore. This probably accounts in part for the stoppage of the work, since it is supposed that considerable ore still remains in the mine, as the ore body has not been worked between the two slopes that penetrated it.

References: N. J. 1868, p. 558; 1873, p. 38–39; 1879, p. 49.

(*292*) *The Barnes Mine.*

The Barnes mine was on the same range as the Daniel Horton mine and about one-half of a mile further northeast.

It was first explored in 1868 on a line of strong attraction, and opened in 1869. It was worked steadily for three years thereafter, yielding several thousand tons of ore.

The vein was exploited for a distance of 500 feet, and in some places to a depth of 100 feet. Its dip was 60° southeast, with an average thickness of 4 feet. Three faults were encountered in mining, but none of them were of any great magnitude. The ore was comparatively lean.

References: N. J. 1868, p. 558; 1873, p. 39.

(*293*) *The Thorp Mine.*

The Thorp mine was in Chester Township, Morris County, about one-half of a mile south of Ironia, and almost on the line between Chester and Randolph townships.

Nothing is known of the operations of this mine. It was one of a series of small openings, from which surface ore was taken. It probably never yielded much ore.

Reference: N. J. 1883, p. 96.

(294) *The Henderson Mine.*

The Henderson mine, in Randolph Township, Morris County, was about one-fourth of a mile east of Ironia, and a few hundred yards south of the road to Calais.

The mine was first opened in 1868, but was worked only for a very short period. It was abandoned before 1873. This was another one of the small openings so abundant in this vicinity from which weathered surface ore was taken.

References: N. J. 1868, p. 558; 1873, p. 43; 1879, p. 49.

(295) *The George Mine.*

The George, or Logan, mine was in Randolph Township, Morris County, about 1 mile northeast of the Henderson mine and the same distance from Ironia.

The mine was worked before 1855 on the southwesterly of two veins 50 feet apart, but was not in operation in this year. The vein worked was from 7 to 9 feet thick and was exploited to a depth of 140 feet and a length of 200 feet. A third vein, 3.5 feet thick, lies about 200 feet northwest of the other two. It was proved for a distance of 150 feet in 1868, and was worked until October, 1873. It was then abandoned. An analysis of this ore gave:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Met. Iron	Authority
72.1	14.2	0.2	0.5	52.2	N. J. 1868, p. 559

References: N. J. 1855, pp. 220–221; 1868, p. 559; 1879, p. 49.

(296) *The David Horton Mine.*

The David Horton mine, in Randolph Township, Morris County, was three-fourths of a mile northeast of the Logan mine and between this and the DeHart mine, on the southwest side of the road between Succasunna and Mt. Freedom.

The mine was worked previously to 1868 on a series of three narrow veins within a few yards of one another, all dipping towards the southeast. The mine was idle in 1868, but it was

operated between this year and 1873 through four shafts, of which the deepest was 100 feet. In 1873 it was abandoned.

Some of the ore was fine-grained and very rich, but the greater portion was mixed with rock, pyrite and apatite. An average analysis of the ore on the bank in 1873 gave:

SiO_2	Fe_3O_4	Al_2O_3	CaO	MgO	TiO_2	P_2O_5	H_2O	Total	Fe	P
16.15	68.48	3.34	4.87	1.94	1.09	3.01	.40	=99.28	49.57	1.30

References: N. J. 1868, p. 559; 1873, pp. 39–40; 1879, p. 49.

(297) *The DeHart Mine.*

The DeHart mine is immediately northeast of the David Horton mine, in Randolph Township, Morris County, about 1.5 miles north of Calais.

Explorations were made before 1868, but no considerable quantity of ore was found, although a strong line of attraction was discovered which extended southwest to the David Horton mine and northeast to the Dalrymple mine. Explorations made a few years later, however, discovered a vein which in places was 14 feet wide. The mine was evidently operated until 1873. It was then closed, and it remained idle until 1879, when it was reopened and worked in connection with the Lawrence mine, which was a few hundred yards to the northwest. At the end of 1884 the mine was again closed, but it was opened again in 1886, and a vertical shaft 65 feet deep was sunk. Since no further mention of the mine is made in the Survey reports it is probable that it was soon afterward abandoned.

Most of the ore mined was the red surface material. This was only a few feet deep in the northwest openings, but was 30 feet to 40 feet deep in the later workings, which were southwest of the old pits. Below this was the ordinary blue ore, which was in four veins that were tested along their strike for 1,200 feet. The ore deposits varied in width from 3 feet to 9 feet. They dipped southeast at an angle of 80° to 85° and pitched northeast. Much of the blue ore was so sulphurous as to be of little value. It is reported that at one time (about 1864) attempts were made to mine the material as a copper ore.

A sample of the surface ore as it was being shipped in 1880 gave:

$Fe = 50.70$; $P = 0.633$; $TiO_2 =$ present. Authority: 10th Census, p. 167.

References: N. J. 1868, p. 559; 1873, p. 40; 1879, p. 49; 1880, p. 104; 10th Census, pp. 166–167; 1883, pp. 96–97; 1884, p. 81; 1886, p. 140.

(*298*) *The Lawrence Mine.*

The Lawrence, or Gordon, mine, in Randolph Township, Morris County, was between the DeHart and Dalrymple mines, probably on the same vein.

It is not known at what time the mine was first opened, but it was worked in 1878, and then closed, to be reopened again in 1880, when it was worked in connection with the DeHart mine until 1883. There were three shafts, of which all were down 110 feet on a vein 2.5 feet wide at the time of closing in 1878. Between the middle and the southwest shafts the vein is reported to be faulted. The shoots of ore are said to have pitched to the southwest.

The later operations carried on in connection with the work at the DeHart mine have already been described.

The ore from the northeast shaft, as mined in 1880, contained:

$Fe = 51.62$; $P = .246$; $TiO_2 =$ present. Authority: 10th Census, p. 167.

References: N. J. 1879, p. 49; 1880, p. 104; 10th Census, pp. 166–167; 1883, pp. 96–97.

(*299*) *The Dalrymple Mine.*

The Dalrymple, or Carbon, mine was immediately northeast of the Lawrence mine, in Randolph Township, Morris County, about 2.5 miles northeast of Ironia village.

It was opened a few years before 1868, on the vein that passed through the DeHart, Lawrence and Trowbridge mines, and was operated until 1876. It was then closed and remained idle until 1879, when it was reported and worked until the middle of 1882. In 1884 the machinery was removed and the mine was permanently abandoned. The reason assigned for the abandonment was distance from the railroad. When in active working condition its annual production was 24,000 tons.

In 1879 there were two groups of openings on the property, about 500 feet apart. The northeastern one was a pit entered by two shafts. The vein which had been worked to a depth of 200 feet varied in thickness between 18 inches and 5 feet. It dipped 75° to 80° southeast. The southwest opening was a shaft near the Lawrence mine. When the mine was abandoned the older shafts were 300 feet deep.

The explorations developed a lens of ore that was 18 feet wide, in its broadest part, but which pinched within a few yards of this point to a layer not over 18 inches wide. This was due largely to a change in the dip of the hanging-wall which cut out the ore body. In places the wall continued uniformly, while the ore was partially replaced by rock. At the northeast end of the mine the vein was faulted.

Much of the ore was lean and consisted of interlaminated magnetite and rock. Several analyses show the character of the ore raised at different times.

	Fe	*SiO_2*	*P*	*S*	*TiO_2*	*Authority*
I.	54.06	18.00	0.25	tr		N. J. 1899, p. 160–161
II.	59.54		0.366		present	10th Census, p. 167
III.	55.92		0.222		present	10th Census, p. 167
IV.	58.61		0.296	0.026		N. J. 1899, p. 170

I. Sample of ore as shipped.
II. Sample from pile of 20 tons at the southwest shaft.
III. Sample from pile of a few tons at northeast pit.
IV. Sample of ore shipped from dump to the Thomas Iron Co. in 1900.

References: N. J. 1868, p. 559; 1873, pp. 40–41; 1879, pp. 49–50; 1880, p. 104; 10th Census, p. 167; 1883, p. 97, 1884, p. 81; 1899, pp. 160–161 and 170.

(300) *The Trowbridge Mine.*

The Trowbridge mine was in Randolph Township, Morris County, adjoining the Dalrymple or Carbon mine on the northeast.

It was being operated in 1868 on a narrow vein, but was soon afterwards closed.

References: N. J. 1868, p. 559; 1873, p. 41.

(301) *The Solomon Dalrymple Mine.*

The Solomon Dalrymple mine was in Randolph Township, Morris County, adjoining the Trowbridge mine on the northeast. It was at the extreme northeasterly end of the range on which were situated the David Horton, the DeHart and the Dalrymple mines.

Explorations were made here just before 1873 and some ore was found, but as to its extent nothing is known. The mine was idle during several years before 1879, and it is probable that it was never operated.

References: N. J. 1873, p. 42; 1879, p. 50.

(302) *The Copper Mine.*

Three different mines have been designated by this name at different times. One was about 1 mile northeast of Chester (see page 438); another was at Ringwood, in Passaic County (see page 482), and the third was 2 miles south of Dover, in Randolph Township, Morris County. The last named was of little importance. It was worked for a short time and was abandoned in 1870.

References: N. J. 1873, p. 42; 1879, p. 50.

(303) *Munson's Mine.*

Munson's mine, in Randolph Township, Morris County, was about one-half mile southeast of the railroad station in Dover.

Two shafts were sunk about the year 1859. They were 120 feet deep, 150 feet apart and connected by a drift. The vein was 4 feet wide, but in this width it included considerable rock. The ore was granular, crumbling and much rusted. During the time the mine was worked it yielded about 16 tons of ore daily.

Reference: N. J. 1868, p. 551.

(304) *The Swedes Mine.*

Swedes, or Sweed's, mine was one of the important mines of 50 years ago. It was in Rockaway Township, Morris County, about 1 mile east of Dover, on the north side of the Morris Canal.

At the time of publication of the report of 1855 the ore had been removed along a distance of 860 feet, and to a depth, at one place, of 175 feet, the power utilized being derived by water (Fig. 28). The mine was worked almost continuously between

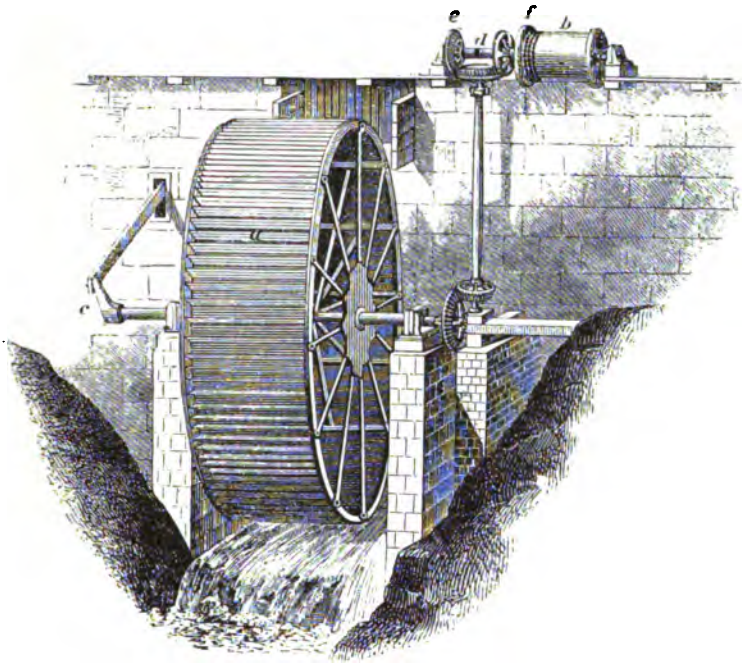


Fig. 28.

Machinery at Swede's Mine in 1855. (From Ann. Rep. State Geologist, N. J., for 1855, p. 240.)

this date and 1875. In the latter year it was closed and in 1882 it was permanently abandoned. At this time the mine was 220 feet deep and 1,300 feet long, and was entered by two shafts and two adits.

Toward the southwest the ore deposit was narrow, measuring at different points from 1 to 3 feet in width. Farther northeast it was 13 feet wide and in the extreme northeast portion of the mine it was 9 feet. Here the ore was mixed with seams of rock. It dipped 57° northwest.

The ore body was irregular in shape. It consisted of a mixture of magnetite and hornblende possessing an indistinct schistosity dipping and striking with the structure of the surrounding gneisses. The vein was

"made up of a series of subordinate beds or seams, mostly composed, as above stated, of mixtures in variable proportions of magnetic iron, black hornblende in crystals of considerable size, some seams, however, being composed of magnetic iron, more or less pure, and some feldspar or quartz." (N. J. 1855, p. 232.)

The foot-wall material resembled the ore in being composed of magnetite and hornblende, but it was more schistose than the commercial ore. In some places the walls were apparently a pegmatite, and a horse in the ore was probably of the same material. Among the constituents of the ore were found veins of calcite, crystals of some zeolitic mineral, zircon and a violet mineral in amorphous incrustations, probably fluorite.

Recorded analyses show the ore to have been quite lean.

	Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Met. iron	Authority
Northeast stopes, ..	66.9	24.6	0.0	0.0	48.5	N. J. 1868, p. 554
Southwest stopes, ..	78.1	20.6	0.0	0.0	56.9	N. J. 1868, p. 554
Southwest stopes, ..	96.3	3.4	0.0	tr	69.8	N. J. 1868, p. 554
Southwest stopes, ..	71.5	17.8	0.0	0.1	51.8	N. J. 1868, p. 554

References: N. J. 1855, pp. 230–234; 1868, pp. 551–554; 1873, p. 46; 1879, p. 56; 1882, p. 70.

(305) *The White Meadow Mines.*

The White Meadow mines comprise an extensive series of openings in Rockaway Township, Morris County, about 2 miles north of Rockaway and the same distance southwest of Hibernia.

The mines were opened before 1840 as the Kitchell and Muir mines, on a vein that was reported to be only 6 inches wide at the surface, but which increased to a width of 2.5 feet at a depth of 30 feet. Before 1855 it had been worked to a depth of 130 feet and along a length of 200 feet. It was actively operated between 1855 and 1868, but before 1873 it had been abandoned.

The vein on which the mine was opened was thought to be the same as that worked in the Beach, Montauk and Hibernia mines. It is more probable, however, that it is a different one, a little to

the east of the Hibernia vein. At the White Meadow mine the ore body was only about 2 feet thick. It dipped 75° southeast.

The only analysis of the ore that is recorded appeared in the report of 1868. It is:

Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Fe	Authority.
59.9	5.2	.0	1.6	45.1	N. J. 1868, p. 559

References: N. J. 1840, p. 29; 1855, p. 230; 1868, p. 559; 1873, p. 47; 1879, p. 56.

(306) *The Beach Mine.*

The Beach mine was an important center of ore production during the middle of the last century. It was about one-fourth of a mile southwest of the southern end of the Hibernia property and about an equal distance northeast of the White Meadow mine.

The ore was discovered about 1785 and was worked to a depth of about 12 feet by its discoverer. About 1833 it was reopened and worked for a short time and then abandoned. In 1853 the property passed under new control and was developed into a mine that produced 1,500 tons of ore annually. In 1855 the excavation was 50 feet deep and 190 feet deep. In 1868 the mine was worked by two companies, its northeast end being known as the Montauk mine. Before 1873, however, both lines were abandoned. In 1880 the Beach mine was again reopened, but how long it was operated is not known. During the Tenth Census year it produced 357 tons. In 1885 it was worked in connection with the Lower Wood mine at Hibernia, but it was again abandoned in the following year.

The outcrop of the ore was about 20 feet below the crest and on the northwest side of the steep hill lying to the south of Hibernia Brook. The ore body was 3.5 feet thick. It dipped 80° southeast and pitched about 15° northeast. A small fault crossed the vein, throwing it about 2 feet to the right. Another fault, with a throw of 22 feet in the same direction, separates it from the ore worked in the Lower Wood mine.

The ore was like the Hibernia ore in containing granular apatite and hornblende. A light-green asbestus occurred in the

hanging-wall next to the ore, and seams of calcite were associated with black hornblende and green feldspar.

Analyses of the ore as recorded in 1868 are as follows:

	Fe_3O_4	SiO_2 and ins.	S	P_2O_5	Fe	Authority.
1—	88.1	19.2	0.0	0.3	63.8	N. J. 1868, p. 561
2—	94.1	4.4	0.0	tr	68.2	N. J. 1868, p. 561

References: N. J. 1855, pp. 226–228; 1868, p. 560; 1879, p. 56; 1880, p. 108; 10th Census, p. 173; 1885, p. 103; 1886, p. 136.

(307) *The Hibernia Mines.*

The Hibernia group of mines comprises the Lower Wood, Crane, Church, Glendon, Scott, DeCamp, Upper Wood and Willis mines of the early Survey reports, situated at Hibernia, in Rockaway Township, Morris County (Plate XII). In 1862 the Glendon or Crane, the Scott or Church, the DeCamp and the Upper Wood mines were taken under the control of the Glendon Iron Company, and thus was inaugurated the policy of consolidation which finally resulted in a splendid property, now one of the most important ore producers in the east. In 1891 the Andover Iron Company purchased the Lower Wood mine and in 1899 the adjoining Church mines, and operated them under the name of the Andover mine. In the same year the DeCamp and Upper Wood lots, as well as the Glendon or Crane lot were bought by Mr. Wharton, who had a few years previously, in 1890, secured the Willis mine. This gave him control of 4,500 linear feet of the ore body. In the early part of 1901 he purchased the Andover property, and thus secured the control of the entire ore belt (Fig. 29).

It is probable that ore was obtained from the Hibernia vein as early as 1722, as at that time a forge was in operation on Rockaway River about a mile west of Dover, and between 1725 and 1730 a small one was built at the village of Rockaway, about 4 miles south of Hibernia. The mine tract was taken up in 1753 by Joshua Ball. Before this time the ore is supposed to have been free to any one who chose to dig it. From 1753 to 1765 "iron works" were operated at Beach Glen. In the latter year the "Adventure furnace" was built at Hibernia, and this during the Revolution manufactured shot and ordnance for the

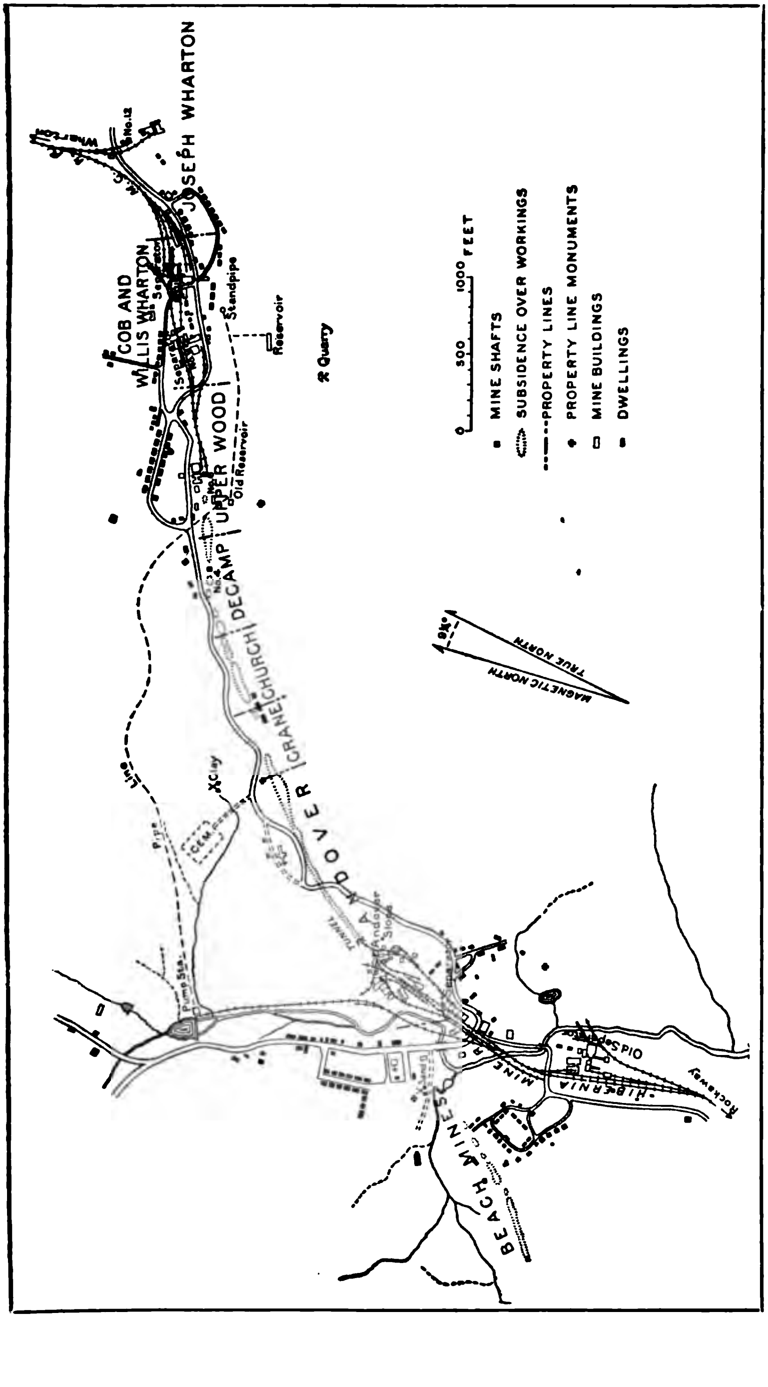


FIG. 29.—Map of magnetite mines at Hibernia, N. J., 1907.

Continental Army. This was afterwards known as the Hibernia furnace. There is no record of the amount of ore produced between 1750 and 1854. In 1850 a little ore was raised to supply the furnaces at Powerville and Beach Glen, but the old Hibernia furnace was in ruins, so that it is probable the quantity was small. The product of the mines between 1854 and 1864 is estimated by Mr. Pullman at 104,521 tons, and from 1864 to 1885 at 1,716,437 tons, being an average yield of 78,020 tons. Between 1901 and 1905 the recorded production is 1,084,567. If we estimate their production between 1886 and 1900 at 1,800,000 tons, their aggregate yield between 1750 and the close of 1906 was about 5,000,000 tons. In 1907 the Andover mine was abandoned, and the ore from its lowest levels was raised through shafts situated further northeast. In the following year all the shafts except No. 12, at the northeast end of the property, were closed, owing to the slack demand for ore.

The deposit on which the openings are situated is over a mile long, being by far the largest "vein" in the State. It differs from all other deposits in its nearly uniform thickness from one end to the other. Definite shoots are lacking, but pinches occur which are simply portions of the vein that are thinner than elsewhere. Of these there are about ten on the property.

At the south end of the vein, near the surface, the ore body was divided into three parallel portions, with thicknesses of from 3 to 5 feet and 1 foot respectively, separated by rock layers 3 feet and 2 feet thick. Further north the three parts became two, and at the north end of the lead, in the Willis mine, these united into a single ore body 7 feet thick. The dip was about 80° to the southeast in the southern portion of the vein and nearly vertical, in some places even to the northwest, at its northern end. At greater depths the divided vein united and became a single ore body, varying in depth between 4 feet and 20 feet, with a uniform dip of about 87° to the southeast.

At a depth of 500 feet in the Lower Wood mine, at the south end of the "vein," barren ground, *i. e.*, ground that was not profitable to mine, developed and made northeast with increasing depth at a pitch of 27°. This was at first regarded

as the bottom rock of the deposit, but on the 24th level of the mine this was penetrated by a drift, which at a distance of 62 feet developed an ore body 8 feet wide. This "barren" ground was only a pinch narrower than usual, lying between the ore body of the Lower Wood mine and that of the Montauk mine to the south. At the north end of the "vein" a little to the northeast of the Wharton (formerly Willis) mine, "barren" rock is again being encountered, under which the ore body pitches at an angle of 45°. But in this there are stringers of magnetite, which suggest that perhaps beyond the pinch there is another ore body.

In 1906 a new ore body is reported to have been developed a few hundred feet northwest of the main body. This contained a lean ore (30 per cent. to 32 per cent. of iron) which at a depth of 75 feet was about 35 feet wide.

The ore of the entire lead is remarkably uniform in character. It is coarsely granular, and in some portions possesses a columnar structure. Through it are disseminated small grains of apatite and particles of dark-gray hornblende, and occasionally a mass of quartz or feldspar. On the walls near the ore body are found occasionally a few narrow veins of calcite. In the New Jersey Survey Report of 1868 there are noted as occurring with this calcite, green and violet-colored fluorspar and crystallized quartz. In the ore itself there were found small hexagonal plates of brown mica, quartz and needles of green tremolite, and chalcopyrite was noted as being associated with feldspar, but whether this was in the ore or the country rock was not stated.

Before 1875 much of the ore was used for Bessemer iron. Later, however, with the fall in price of Bessemer ore the incentive to its development ceased and all the ore was worked together. Until 1884 only the richest material was utilized. Although a magnetic cobber was in operation as early as 1856, the practice of systematic cobbing was not inaugurated until 1884, and in 1896 a separator was built. A second was added in 1901 and a third in 1906. With these to concentrate the magnetite, much of the material that formerly went in the dump is

now classed as ore. It is crushed to 2-inch cubes and passed to a cobber which extracts all particles containing ore. These are then again crushed and passed over separators until most of the magnetite is extracted. In this way material which originally contains from 22 per cent. to 30 per cent. of iron is concentrated to a product with an iron content of from 58 per cent. to 62 per cent. The tailing retains but 8 per cent. to 11 per cent. of the metal.

The installation of the separators, made an economic possibility by the consolidation of all the formerly independent mines on the Hibernia lead, and the improvement in the pumping and hoisting plants, which were also indirectly the result of the consolidation, have increased enormously the producing power of the group of mines and have made it possible to work the ore body profitably to greatly increased depths. The southwesterly openings are already 1,200 feet deep and the northeastern one 1,500 feet, both penetrating the rock to a distance of 600 feet beneath sea level.

Analyses of the Hibernia ore have been published from time to time. These show its quality to be as uniform as its appearance. Variations in the proportions of iron and phosphorous indicated are explainable as the result of more or less careful cobbing.

The analyses of the chemists of the 10th Census are the only ones available that give any information of the characteristic difference of the ore from different points of the vein. These are:

Across northwest vein of Scott mine, ...	*Fe* = 58.22	*P* = 0.407
Across southeast vein of Scott mine, ...	57.27	0.139
Samples from 24 carloads of mixed ore from the Glendon, Scott, DeCamp and Upper Wood mines,	53.75	0.364
Sample from 14 carloads of Lower Wood ore, ...	56.00	0.223
Sample from canal-boat load of Willis (Wharton) mine ore, ...	49.82	0.343

Other analyses are as follows:

	Fe	*P*	*S*	*Authority*
Average sample, shipping ore, 1908, ..	62.80	0.231	0.014	R. B. Gage
Single sample, 1908, ...	59.87	0.010	0.026	R. B. Gage

More complete analyses follow:

	I.	II.	III.	IV.
SiO_2,	6.925	7.14	9.25	12.08
Al_2O_3,	5.175	1.23	1.98	1.63
Fe_2O_3,	56.811	60.89	55.71	56.21
FeO,	26.438	25.94	26.64	26.39
MgO,	.998	1.40	1.11	0.88
CaO,	1.582	1.31	1.89	1.08
Na_2O,	....	0.08	0.57	0.17
K_2O,	....	0.13	0.12	0.15
H_2O +,	....	} 0.25	0.43	} 0.17
H_2O —,	....		0.56	
TiO_2,	....	1.25	0.54	1.21
P_2O_5,	0.803	0.529	0.86	0.023
SO_3,	....	0.034	(S)=0.07	0.065
FeS_2,	0.711	....	....	....
V_2O_3,	....	0.15	0.14	0.21
MnO,	....	0.03	0.05	0.07
Fe,	tr	....	....	....
CO_2,	1.045	....	0.35	....
	100.488	100.153	100.27	100.338
Less O =	.020			

I. Analyst, L. C. BIERWITH.

II. Average sample, Hibernia ore, 1908. Analyst, R. B. GAGE, N. J. Geological Survey. Cr_2O_3, NiO, CoO, BaO, and SrO were sought but not found.

III. Average sample, Hibernia ore, 1906. After magnetic cobbing. Analyst, W. T. SCHALLER. Small quantities of Cr_2O_3 and NiO were also found. ZrO, BaO, SrO, Li_2O, CuO, CoO, and ZnO were looked for but not found.

IV. Sample good ore. Single piece. Analyst, R. B. GAGE. Contains little Cr_2O_3, but no iO, CoO, BaO or SrO.

References: N. J. 1840, p. 30; 1855, pp. 221–226; 1868, pp. 561–564; 1872, p. 16; 1873, p. 47; 1879, pp. 56–57; 1880, p. 108; 10th Census, p. 173; 1883, pp. 116–117; 1884, pp. 90–91; 1885, pp. 103–104; 1886, p. 143; Trans. A. Inst. Ming. Eng., Vol. 14, 1886, p. 904; 1890, pp. 63–65; 1891, pp. 247–248; 1893, pp. 364–367; 1896, pp. 330–333; 1897, pp. 321–322; 1898, pp. 235–236; 1899, pp. 156–157; 1900, pp. 202–203; 1901, pp. 144–148; 1902, pp. 120–122; 1903, pp. 105–106; 1904, pp. 298–300; 1905, pp. 317–318; 1906, pp. 176–177; 1907, p. 172.

The Split Rock Pond Mine.

The Split Rock Pond mine is at the north end of Split Rock Pond, in Rockaway Township, Morris County.

The mine is an old one, the early history of which is unknown. It was reopened in 1873 and worked during 1874 and a portion of 1875, during which time a shaft 100 feet deep was sunk. It was then closed until 1878, when it was again reopened and operated intermittently during the succeeding two years. In the census year 1879–1880 about 560 tons were raised.

During this period two leads were developed by a shaft 100 feet deep. They were 50 feet apart. The eastern one was more than 14 feet across, 7 of which, toward the foot-wall, consisted of alternate strings of granular ore and mica. The foot-wall or west "vein" contained a shoot of rich ore 25 feet high and 8 feet wide. Nothing is said in any of the reports of the mine as to the existence of limestone in it, although great fragments of this rock impregnated with magnetite are still to be found on its dumps.

North of the shaft, near the Charlottesburg road, and for a distance of about a mile along this road, a number of pits were dug, and in most of these ore was found. The most northerly of these openings was later developed as the Wood mine (page 422).

An analysis of the ore raised in 1875 yielded:

$Fe = 63.4$; $P = 0.011$; $S = 0.07$; Authority: N. J. 1879, p. 58.

References: N. J. 1873, pp. 47–48; 1874, p. 23; 1879, pp. 57–58; 1880, p. 108; 10th Census, p. 174; 1883, p. 118; 1890, p. 104.

(308) The Stony Brook Mine.

The Stony Brook, or Pikes Peak, mine was in Pequannock Township, Morris County, about midway between Charlottesburg and Split Rock, and about a mile east of a line between the two points. On the topographic maps of the New Jersey Survey the mine openings are represented as being on the west side of Stickle Pond (now better known as Kinney's Pond).

There are five openings from which ore has been taken. One is reported to have been made by the London Company over 140 years ago. The others were sunk in 1866–7, the deepest being 30 feet. The place was worked for a short time and then closed down. Work was again resumed in 1870, and 100 tons of ore were raised and made into blooms during the following year. In 1880 the mine was abandoned.

There were several small deposits developed, of which the thickest was only 3 feet across. Their dip is 60° southeast. Just outside the original line, however (on the Righter lot), there is reported to be 13 feet of ore and rock.

The analysis of a specimen of the ore gave:

Ins.	Fe_3O_4	TiO_2	P_2O_5	S	Mn	Fe	P	S	Authority
8.10	89.33	1.50	tr	0.0	0.0	64.69	tr	0.0	N. J. 1876, p. 54

A later analysis showed:

$Fe = 63.45$; $P = $ tr; $S = 2.03$; $TiO_2 = 0.30$; $Mn = 0.0$. Authority: N. J. 1880, p. 109.

References: N. J. 1868, p. 556; 1873, p. 51; 1876, pp. 54–55; 1879, pp. 60–61; 1880, p. 109; 10th Census, p. 174; 1883, p. 119; 1884, p. 92; 1890, p. 105.

(309) *The Tellington Mine.*

The Tellington mine was in Pompton Township, Passaic County, about 4 miles northwest of Wanaque, and near the road through Stony Brook valley leading to West Milford.

Three shafts were sunk in 1873 within a distance of 100 yards in the line of the vein, which dipped 40° southeast. The ore is more than 5 feet thick in the southern opening, with well-defined walls. It was lean, but otherwise was of good quality, as it contained but little phosphorus and no sulphur. Further north the vein was only 2 feet wide, and was a trifle richer. Here it dipped to the northwest.

About 200 tons of ore were raised during the year, but none was shipped. Shortly afterwards the place was abandoned.

References: N. J. 1874, pp. 25–26; 1879, p. 61.

(310) *The Cook Mine.*

One of the openings known as the Cook mine, is in West Milford Township, Passaic County, on the west side of the road between Bloomingdale and West Milford, near where it crosses Posts Brook.

Nothing is known about the place except that it is an area of fairly strong magnetic attraction.

(311) *The Board Mine.*

The Board mine was on the top of a knoll about 2 miles northwest of Boardville and a few hundred yards east of the road between this place and Hewitt, in Pompton Township, Passaic County.

The mine was first opened in 1872 on a vein 9 feet wide, dipping southeast about 30°. This vein was worked for a distance of 100 feet and to a depth of 70 feet. A second opening, made a short distance northeast of the first one, was on a second parallel vein 50 feet further east. About 11,000 tons were shipped before the close of 1873. After this the mine was closed to remain idle until 1882. Explorations were begun again in this year, and several fair-sized veins of lean ore were uncovered a short distance north of the old mine. The ore was composed mainly of quartz and magnetite with very little feldspar and hornblende, and no noticeable apatite or pyrite. Other explorations seemed to indicate the presence of a considerable quantity of good ore, so the mine was again opened in 1883 and operated until near the end of 1884, when it was closed down on account of dullness in the ore market. The ore was compact and apparently siliceous.

References: N. J. 1873, p. 52; 1879, p. 61; 1882, p. 71; 1883, p. 120; 1884, p. 92.

THE WOODHULL MINE BELT.

This is a belt of openings on veins of lean ore. So far as is known from actual explorations, the belt begins about three-fourths of a mile east of Fairmount and runs northeast to Split Rock Pond. In this distance of 22 miles there have been about ten explorations, from only three of which ore has been shipped. In every case the ore was lean.

(312) *The Welch Farm Exploration.*

The Welch Farm exploration was about one-half of a mile east of Fairmount, on the north side of the road to Pottersville, in Tewksbury Township, Morris County.

A little ore was obtained, but nothing is known of its character. The openings were made some time before 1884. Judged by the size of the dump, the place was never important.

Reference: N. J. 1873, p. 47.

(313) *The Langdon Mine.*

The Langdon mine, in Washington Township, Morris County, is one mile south of Hacklebarney, at the extreme southern end of the range next east of that passing through Chester.

A line of attraction 2,000 feet long was observed here and several pits were put down in 1879, finding some ore. The work of exploration was continued during 1880 and a mine was opened in this year.

At first the ore was worked by open pits, but later these were timbered and work was continued by underground methods.

In 1882 the mine was closed to await an increase in the price of ore. It was opened again in the early part of 1886 and operated until the fall of that year, when operations were transferred to a point several hundred feet to the northeast.

As no work at the locality has been reported since 1886, it is probable that the mine was abandoned about that time.

In the earlier work, *i. e.,* that to the southwest, two shoots of ore were found pitching southwest at an angle of 20°. The dip was moderate to the southeast. In the southwest shoot the ore varied from 10 to 15 feet in thickness. West of this, and separated from it by a horse of soft rock 2 to 4 feet thick, was a second deposit 3 feet to 5 feet thick. In the northeast shoot the vein was 11 to 15 feet wide. A fault in this threw the vein to the left, displacing it about 7 feet. Between the two shoots the workings indicated a second and greater fault, which is apparently to the right.

In the later, northeast workings, a bed 7 feet to 14 feet wide was exposed. This dipped 45° southeast and pitched 15° southwest. There is no evidence that this deposit is in any way connected with that to the southeast.

The surface ore to a depth of 38 feet was red and free from sulphur. Beneath this it was hard, and contained some pyrite and a little mica.

The production was at the rate of 1,400 tons monthly in 1886.

References: N. J. 1879, p. 46; 1880, p. 103; 1883, pp. 85-86; 1885, p. 97; 1886, p. 146.

(314) *The Rarick Farm Explorations.*

The Rarick Farm explorations were a mile southwest of Hacklebarney on the east side of the road leading to Fairmount, in Chester Township, Morris County.

The place which was across the road from the Langdon mine was first explored in 1873. Some ore was found, but it was evidently in insufficient quantity to warrant working.

References: N. J. 1873, p. 31; 1879, p. 46.

(315) *The Pitney Mine.*

The Pitney mine was less than one-fourth of a mile northeast of the Langdon mine and on the same range. It was in Chester Township, Morris County, about a mile south of Hacklebarney and just west of the Rarick Farm mine.

It was first explored in 1873, but very little is known of the result, except that before 1879 some of the surface ore had been shipped, and during 1880 and 1881 a large quantity of ore (over 2,500 tons) was sent to the Pequest furnace. At the close of the latter year the mine was abandoned.

Later a vein 12 to 15 feet wide was discovered in a shaft in which the pitch was to the southwest. The ore was lean and was not further explored. The total yield of the various openings to June, 1880, was estimated at 6,700 tons. The ore was washed before shipment. A sample of the washed ore taken by the agents of the 10th census from a pile of 25 tons gave:

Fe=50.84; S=0.142; P=0.112. Authority: 10th Census, p. 164.

References: N. J. 1873, p. 31; 1879, p. 46; 1880, p. 103; 10th Census, p. 164; 1883, pp. 86–87.

(316) *The Gulick Mine.*

The principal mine of this name was northeast of the Hacklebarney mines. It has already been described in another place (see page 431). The Gulick mine now under consideration was on the north bank of the Black River about one-third of a mile east of Hacklebarney, and about a mile northeast of the Pitney mine, in Chester Township, Morris County.

It was never of any importance.

(317) *The Child Mine.*

The Child mine, in Chester Township, Morris County, was situated about 1 mile east of Hacklebarney and 1.5 miles south of Chester. It was three-fourths of a mile west of the Harden mine and one-half of a mile east of the Gulick mine, about midway between the two ranges on which these mines are situated.

The place was explored in 1874 and a small quantity of ore was removed. Otherwise the property has not been worked.

Reference: N. J. 1883, p. 95.

(318) *The Woodhull Mine.*

The Woodhull mine was on the same range with the Budd and Gulick mines, about one-half of a mile south of Chester village, in Chester Township, Morris County, on the road between Chester and Gladstone.

It was opened about 1870 and pretty thoroughly explored, but nothing being found that was very promising, it was soon abandoned, and was idle in 1873. It was started anew in the latter part of 1885 and 377 tons of ore were raised. It was again closed in 1886, after a shaft had been sunk south of the road.

In some places the ore body was 8 feet wide, but as it was replaced in depth by a micaceous gneiss, it soon became too narrow to work. The dip near the surface was 70° southeast. This diminished until in the deepest explorations it was only 50°. The ore was reported to be compact and rich.

Between this mine and the Budd mine, about 1 mile to the northeast, two faults were uncovered, which threw the vein about 200 feet in opposite directions, the south one to the right and the north one to the left.

References: N. J. 1873, p. 32; 1879, p. 46; 1883, p. 95; 1885, p. 99; 1886, p. 153.

(319) *The Budd Mine.*

Of the two mines of this name (see also p. 289), one was situated about one-fourth of a mile east of Chester, in Chester

Township, Morris County, about 1 mile northeast of the Woodhull mine, from which it was separated by two faults.

It was opened in 1867, uncovering a vein of ore from 6 to 8 feet wide, and was worked a short time. It was, however, abandoned before 1873.

References: N. J. 1868, p. 558; 1873, p. 32; 1879, p. 46; 1883, p. 95.

The De Camp Mine.

There have been several mines described in the literature under this name. One is in the Hibernia group (page 454), another was known also as the Rockaway Valley mine (page 488), and the third, the one here referred to, was in Chester Township, Morris County, 1 mile northeast of the village of Chester and near the road to Dover. Its exact situation is not known.

The mine was opened in 1869 by five shafts, one of which is reported to have been 80 feet deep. The ore is said to have looked good, but none was ever shipped, so far as is known. In 1874 the place was abandoned.

References: N. J. 1873, p. 38; 1879, p. 49.

(*320*) *The Meriden Mine.*

The Meriden mine was situated near the old Meriden forge, near Meriden, in Rockaway Township, Morris County.

Nothing is known of the mine except that the openings were made before 1868. Its exact location has not been ascertained, but it was probably on the south side of the road, between Meriden and the Wharton mine, where there are now to be seen two openings.

References: N. J. 1868, p. 556; 1873, p. 47; 1883, p. 118; 1884, p. 91; 1890, p. 104.

(*321*) *The Righter Mine.*

The Righter mine is west of Meriden, on the road leading to Split Rock, in Rockaway Township, Morris County.

It was opened before the year 1872, but nothing is known of the character of the deposit or the quality of its ore, except that

it was reported to be good, and to contain a small percentage of titanium.

References: N. J. 1873, p. 47; 1883, p. 118; 1884, p. 91; 1890, p. 104.

(322) *The Cobb Mine.*

The Cobb mine, formerly known as the Split Rock mine, is east of about the center of Split Rock Pond, in Rockaway Township, Morris County.

Before 1868 the ore body had been traced for a distance of nearly a mile in a northeast direction, and had been opened up and worked down to the water level for half this distance. In 1873 the mine was not being worked. It was reopened in 1878 and operated until 1881, since which time it has been abandoned. At the time of its abandonment it was reported to be 120 feet deep.

At both ends of the undeveloped portion of the lead the outcrop passes under valleys into which the ore has not yet been followed by actual mining. At its south end the ore body is 2.5 feet thick, with a dip of 70° southeast. Further north its width increased to 5 feet and its dip to 78°. In its widest portion a narrow streak of rock runs through the center of the ore. From the descriptions given in the "Geology of New Jersey" it seems probable that the ore ocurs in two shoots, pitching at a low angle to the northeast.

During the census year 1879–1880 the mine produced 1,288 tons of ore. About half of the material raised was rock. The ore was roasted and crushed before going to the forge.

An analysis of a sample of the calcined ore taken from a pile of 25 tons gave:

Fe=59.79; P=0.426. Authority: 10th Census, p. 174.

References: N. J. 1868, p. 556; 1873, p. 47; 1879, p. 57; 1880, p. 108; 10th Census, p. 174; 1884, p. 91; 1890, p. 104.

(323) *The Split Rock Pond Veins.*

In addition to the ore body at the north end of Split Rock Pond there are known to be several veins of ore on the east side of the pond. These were opened in 1873.

Reference: N. J. 1873, p. 47.

THE RINGWOOD BELT.

The Ringwood belt of mines begins at a point about 2 miles west of Lebanon, passes along the southeast side of Split Rock Pond, and leaves the State north of Ringwood. South of the Rockaway River it has been explored by eight or nine comparatively unimportant openings, only one of which, the Combs mine, ever became a shipping enterprise. North of the river the case is entirely different. Practically all of the openings were developed into shipping mines. Except in the case of the Ringwood mines, however, the ore was comparatively lean. At Ringwood the belt widens and includes a large number of parallel veins that suggest the existence of a mineralized zone.

(*324*) *The Large Mine.*

The Large mine, or the Lebanon mine, was about 2 miles southwest of Lebanon and 1 mile west of Round Valley, in Clinton Township, Hunterdon County.

This property was explored about 1872, and a shaft 95 feet deep was sunk on a vein of mixed ore and rock 6 to 8 feet wide. The vein ran east-west, but in neighboring pits the strike was northwest. At many places the ore was mixed with hornblende as thin strings or veinlets, and, when followed along the strike, it was often found to be replaced entirely by this mineral. There is a great quantity of pegmatite in the rock on the dump. Where pegmatite is in contact with the Pochuck gneiss, which constitutes the principal rock associated with the ore, there have been developed in the latter large crystals of hornblende.

The mine was apparently worked until 1875, during which time several hundred tons of ore were raised. It was again operated for one month between June, 1879, and June, 1880, and produced 100 tons of ore. It was probably again worked later, for in 1899 it was claimed that 1,200 tons of ore were on the dumps.

Fe	*SiO_2*	*P*	*S*	*TiO_2*	*Authority*
41.50	20.40	1.66	2.74	0.47	N. J. 1899, p. 166
45.075	14.185	1.625	3.634		N. J. 1899, p. 166

References: N. J. 1873, p. 28; 1879, p. 43; 10th Census, p. 164; 1899, p. 166.

(325) *The Bartle Mine.*

The Bartle mine is in Washington Township, Morris County, about 1.75 miles northwest of Pottersville.

In the report for 1873 the first opening was reported to be on a vein 5 feet wide, but this was stated to be only one-half of a mile northwest of Pottersville. Later the vein is described as being 10 feet wide and as dipping steep to the southeast.

The ore was hard and contained some pyrite. A small quantity was shipped.

References: N. J. 1873, p. 30; 1879, p. 46; 1883, p. 85.

(326) *The Harden Mine.*

The Harden mine was about 1.5 miles south of Chester, in Chester Township, Morris County, on the south side of the road to Pottersville.

The mine was explored in 1869 and a little ore in small veins and strings was found, but nothing was developed sufficiently promising to warrant further work.

Reference: N. J. 1873, p. 32.

(327) *The Quimby Mine.*

The Quimby mine was in Chester Township, Morris County, a little over a mile south of Chester and a short distance east. It lay between the Harden and the Tiger mines and about one-quarter of a mile southwest of the latter. Considerable ore was mined here before 1883 but no information as to the quantity raised or its quality are obtainable.

Reference: N. J. 1883, p. 95.

(328) *The Tiger Mine.*

The Tiger mine, in Chester Township, Morris County, was about one-quarter of a mile northeast of the Quimby mine, and about 1 mile southeast of Chester.

The vein was reported as being 3 feet wide, but the ore was in bunches and was sulphurous. About 300 tons were mined before 1883 and then the place was abandoned.

Reference: N. J. 1883, p. 85.

(329) *The Skellinger Mine.*

The Skellinger mine, in Randolph Township, Morris County, was 1.5 miles southeast of Ironia and one-eighth of a mile southwest of the Combs mine, on the south side of the road to Mendham.

It was opened in 1878 and worked until the close of 1880. By June, 1880, there had been raised about 9,840 tons of ore, which was of the same character as that of the Combs mine.

Two other mines of the same name were in the vicinity of Chester (see pages 436 and 442).

Reference: 10th Census, p. 166.

(330) *The Combs Mine.*

The Combs mine, in Randolph Township, Morris County, consists of several openings about 1.25 miles southwest of Calais, on the opposite side of the road from the Skellinger mine.

The mine was first opened, so far as is known, about 1828 and worked a short time. It was reopened in 1864, but was again closed several years before 1873. Later it was again reopened, and by 1879 it had been worked for a distance of 600 feet in length by different parties through two shafts, one 100 feet and the other 60 feet deep. A few years later it was abandoned permanently. The yield during the census year (1879–1880) was 5,480 tons.

The vein on which the work was done was long and continuous and had a dip of 40° to 45° southeast. It had been mined at five points before 1868, the ore having been removed from a breadth of 1 to 12 feet. The foot wall was said to be smooth and perfect, but there was a very gradual transition between the "vein" and the hanging wall.

The ore is reported to have contained considerable disseminated feldspathic rock, making it rather lean, though near the hanging-wall there was a layer of pure magnetite. It was mixed with Spanish ore and used in the manufacture of Bessemer pig.

A sample taken from the shaft at the southwest end of the property gave:

Fe=37.15; P=0.036; TiO_2=Present. Authority: 10th Census, p. 166.

References: N. J. 1868, p. 550; 1873, p. 42; 1879, p. 50; 1880, p. 104; 10th Census, p. 166.

(331) *Frenchman's Mine.*

Frenchman's mine was about 2 miles southeast of Dover and one-half mile southeast of Union, in Randolph Township, Morris County.

There is no record of the mine in any of the literature on the region.

(332) *The Beach Glen Mine.*

The Beach Glen mines are about 1 mile southeast of Hibernia, on the southeast side of the hill, on whose northwest side is the Hibernia deposit.

The first openings were made about 1808, when the surface was stripped and the ore excavated from a depth of a few feet. It is not known how long work continued, but it could not have been for very long, since the place was abandoned and then re-opened in 1851. At this time two openings were made, one on the southwest edge of the hill and the other 400 feet further northeast, apparently on the same lead.

There is no record as to whether the mine was worked continuously from this time to 1868 or not, but in the latter year it was being operated and it continued in operation until 1875, when work was again stopped. It was reopened in 1879 and ore was taken from two veins. Later the operations were concentrated on the western vein, and this was worked until September, 1885. The ore is lean but of Bessemer grade. With the influx into the market of an abundance of good Bessemer ore from the

Lake Superior region, it became unprofitable to mine the lean ore and market it in its natural condition.

Experiments, therefore, were made in concentrating the ore, which averaged at this time only 41.11 per cent. of iron. It was crushed and jigged with the result that the percentage of the metal was increased by 50 per cent. and the phosphorus content diminished 66 per cent. One ton of concentrate carrying over 65 per cent. in Fe required 2.73 tons of crude ore to produce it. The composition of the material before and after concentration is represented by the following figures:

	Fe	*P*	*P in 100 pts. Fe*
Crude ore,	41.75	0.0643	0.1534
Concentrates,	65.50	0.0224	0.0342

Evidently, however, the process was not regarded with much favor by investors, for the mine was not reopened until 1896, when it was worked for a short period and 500 tons of ore were removed. Two years later, in 1898, the property was leased to Joseph Wharton and operated until November 1, 1900, to secure ore for concentration at Hibernia. In the first of these years 900 tons of crude ore averaging about 41 per cent. Fe were concentrated, with a resulting yield of 400 tons of concentrates carrying 60 per cent. of Fe and 0.009 of P. In 1900 the covering became so thick that the old mine was abandoned. Three shafts were, however, sunk on the west vein and underground work was inaugurated. At a depth of 475 feet a rich lead of ore was encountered with a thickness of 14 feet. This dipped northwest where first met with, but turned to 75° southeast with greater depth. The ore ran 56 per cent. to 60 per cent. Fe and 0.003 per cent. to 0.009 per cent. P, with no sulphur and no titanium. About 7,000 tons of ore were taken out, but the price of ore falling the mine was closed in 1903. Since this date there has been no work done.

The ore thus far discovered in the vicinity of the mine is in three veins, of which the largest and the one most mined is the northwestermost. This is from 5 to 10 feet wide. It is contorted into slight folds, in which the rocks vary in dip from 75°–80° northwest to 70° southeast, the northwest dip being near the surface. The richest ore was obtained from the trough of the

fold. Further northeast the "vein" is composed of narrow laminæ of magnetite from one-half to 2 inches thick, alternating with gneiss, the whole being 7 feet across.

The second important vein is 200 feet further southeast. It is characterized by the possession of a great deal of biotite or other dark mica. This was opened up in 1868 to a depth of 90 feet. The dip of the deposit was 70° northwest and thickness 8 feet. Its pitch was about 15° northeast. During the operations it was observed that the richest ore lay across the foot-wall in a band 2 or 3 feet in thickness.

The other vein is 100 feet further east, and has not been much worked. The ore in this vein contains 64 per cent. Fe and only .06 per cent. P, but it is only 16 inches thick and consequently is unprofitable to mine.

The ore in all the other "veins" thus far opened is lean. From observations made on the walls of the largest opening to the west it is apparent that much of the ore taken from this opening was a magnetitic pegmatite. At all events a pegmatite is now to be found at the end of the opening in the line of strike of the ore removed.

During the census year 9,486 tons were raised. Analysis of this lot by the chemists of the 10th Census gave:

Fe=48.63; *P*=.025; *Cr.*=present. Authority: 10th Census, p. 172.

References: N. J. 1855, pp. 228–230; 1868, p. 554; 1873, p. 47; 1879, p. 57; 10th Census Report, p. 172; 1880, p. 108; 1883. p. 118; 1884, p. 91; 1885, p. 104; 1886, p. 136; 1890, p. 104; 1896, p. 330; 1898, p. 237; 1899, p. 155; 1900, p. 201; 1901, p. 144; 1903, p. 105.

(333) *The Tichenor Diggings.*

The Tichenor diggings, made between 1868 and 1872, are a short distance northeast of the Beach Glen mine, on the strike of the vein, in Rockaway Township, Morris County.

Three shafts were sunk and small quantities of ore were found. In 1872 the mine was closed because of the financial depression. It has not been reopened since unless it was worked in connection with the Beach Glen mine during 1879–85.

Reference: N. J. 1873, p. 47.

(334–335) *The Wanaque Mines.*

The Wanaque, or Wynokie, mines, in Pompton Township, Passaic County, are about 2.25 miles west of Midvale. The openings are two in number, about one-half mile apart.

The southern mine has been known at different times as (334) the London, the Iron Hill and the Blue mine. The northern one has been called the (335) Laurel, the Red and the Laurel Hill mine. Both were worked for many years prior to 1857, the former having been opened by the London Company near the close of the 18th century. The mines were idle until 1886, when the London mine was reopened by a slope 100 feet deep and a drift 50 feet long running north 40° west along the strike of the deposit. It was, however, operated for a short time only. It was reopened in 1890, and again worked for a short period, during which over 8,000 tons of ore were raised and two roasters were erected. Shortly after this date it was again closed, to be reopened in 1905. At this time the mine was cleaned out, but so far as known no ore was raised.

The Laurel Hill mine was opened by a tunnel in the side of the hill, about three-fourths of a mile north of the London mine. Before 1857 about 60 feet of the vein had been developed. It is not known how long the mine was idle, nor how many times it was tested. From the character of the dump-heap it is inferred that it was re-explored about 1890.

The vein at the London mine was 9 feet to 10 feet thick. It had been worked for a distance of 150 feet before 1868. Later the workings were extended to 500 feet in length on an ore body that widened to 16 feet. The dip was nearly perpendicular. The ore body pitched 58° northeast. It was supposed by the operators that the main vein, which had the usual northeast strike, was split and that a second smaller arm ran more nearly north.

The ore was compact and hard. It contained considerable hornblende and mica and was intermixed with a great deal of rock. After being cobbed it yielded a non-Bessemer product containing 54 per cent. Fe and a great deal of sulphur.

The Laurel Hill vein was 4 feet thick. Its dip and pitch were like those of the London mine. A great deal of ore is said to have been removed from it, but no record of the amount has been seen.

References: N. J. 1868, pp. 545–546; 1873, p. 52; 1879, p. 61; 1886, p. 152; 1891, pp. 248–249.

(336) *The Rheinsmith Farm Explorations.*

The Rheinsmith Farm explorations were 2.5 miles northwest of Midvale and one-half mile southwest of Stonetown, in Pompton Township, Passaic County.

Considerable work done here in 1873–1874 uncovered a wide breadth of lean ore on a long and steady line of attraction. No workable deposit was found. On the dumps there is considerable pegmatite.

References: N. J. 1874, p. 26; 1879, p. 61.

(337–344) *The Ringwood Mines.*

The Ringwood mines comprise a group of pits and shafts, some of which are among the oldest in the State. They are about 4 miles east of Greenwood Lake, in Pompton Township, Passaic County (Plate XIII).

Some of the ore deposits in this place were well known before the American Revolution, and nearly all of the older openings were evidently made before 1740, as a blast furnace was built at Ringwood in this year. As early as 1840 Rogers described the details of the ore veins, of which he knew two about 200 feet apart. The southeasterly one had been explored for 3 miles along its length by a number of pits, the southwesternmost of which was 40 feet deep and 350 feet long. About 100 feet northeast of this was the Blue mine, which was likewise a pit, 100 feet long and 50 feet deep. Half a mile northeast of this was the Mule mine—a pit 300 feet long and 70 feet deep. Southeast of this a short distance was a small pit known as the Blue Hole, and a short distance to the northwest of the main mine was another small pit on a rich lens of ore that was called the Henion mine.

Northwest of the Mule mine was the Cannon mines, where the ore body in places was 40 feet wide. Further to the northeast was the Peter mine, which was worked by a shaft and a pit. The ore here was 50 feet wide in one place. and had already been removed to a depth of 70 feet. Continuing toward the northeast, the next mines in order were the Spanish Hope and the Good Hope mines. These two mines were extensively wrought before the Revolution. The Good Hope mine was reopened about 1820, but was soon thereafter abandoned. In 1840 the mine pit was 60 feet deep.

The northwestern vein had been little explored in these early days. At its southwest end it was opened through a length of 100 feet and to a depth of 30 feet, but was otherwise unexplored.

Later additional openings were made on the property, and these are grouped in five lines, apparently on as many distinct veins. Beginning with the southeast vein, and at the southwest end of each vein, these mines were known as:

1. The Blue, Hard, Cook, Mule, Little Blue and Bush mines. The Wood mines were also in this range.

2. The Cannon, St. George, Miller and New Miller mines.

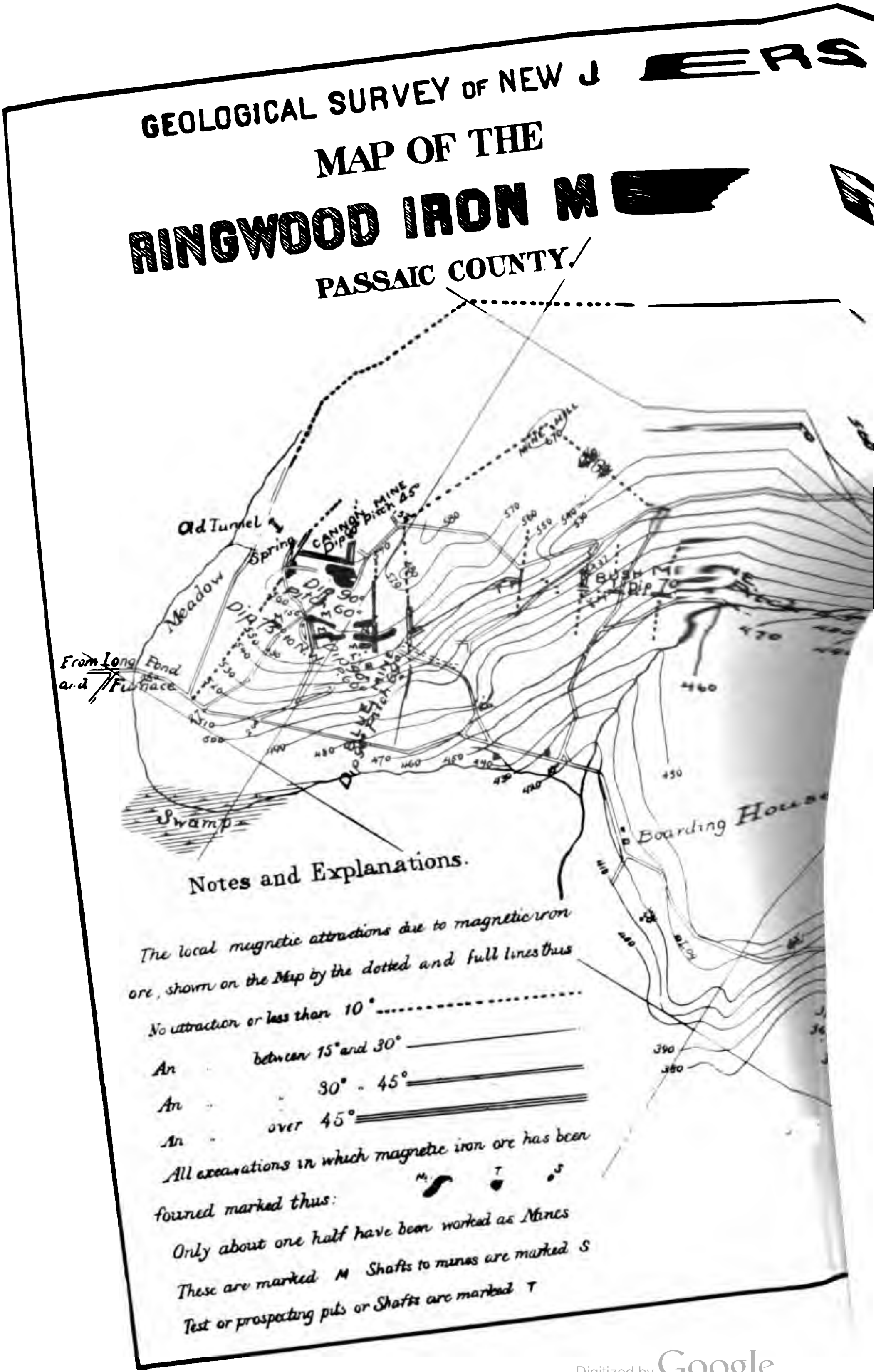
3. The Keeler, Little Red, Winslow and Ward mines.

4. The Cooper mine, and

5. The Peter, New Peter and the Hope mines. The Oak mine was also in this range.

Lines of attraction connect the openings on the several ranges and extend northeast into New York. On the southeast range there were no less than seven distinct openings, of which four were of considerable extent. The Hard mine was a little to the west of the others, but all were so closely crowded that it is almost impossible at the present time to distinguish their respective limits (see Plate XIII).

A review of the descriptions of the mines in the group indicates the presence of a series of distinct shoots varying greatly in shape. Thus the Cannon shoot was a flattened cylinder with a greater breadth than height, other shoots were more nearly square in cross-section, while still others possessed the usual lens shape. The ore was apparently in a Pochuck gneiss cut by


GEOLOGICAL SURVEY OF NEW J ERS
MAP OF THE
RINGWOOD IRON M
PASSAIC COUNTY.
Old Tunnel
Spring
CANNON MINE
Meadow
From Long Pond
and Furnace
BUSH M
Swamp
Boarding House
Notes and Explanations.
The local magnetic attractions due to magnetic iron ore, shown on the Map by the dotted and full lines thus
No attraction or less than 10°
An between 15° and 30°
An 30° - 45°
An over 45°
All excavations in which magnetic iron ore has been founed marked thus:
Only about one half have been worked as Mines
These are marked M Shafts to mines are marked S
Test or prospecting pits or Shafts are marked T

pegmatite. Through this run wide veins of magnetite parallel to the gneissic structure. Magnetite is present also in nests in the pegmatite and as a matrix enclosing the feldspar. In other instances it is enclosed within the feldspars. The dips of all the ore bodies were southeast at fairly high angles, and their pitch was high to the northeast. In the pinches between the shoots the ore in some cases became very thin, and in others was cut out completely. In the early openings the leaders of ore passing through the pinches were not traced to any considerable distance, so that the presence or absence of shoots other than those that outcropped or were near the surface was not proven. In the later workings of the Peter mine, however, it has been clearly shown that in this case, at any rate, there is a succession of shoots such as prevails in other portions of the Highlands.

A study of the positions of the groups of known shoots with respect to one another led Nason to suggest that their occurrence in so many lines so closely crowded is due to repetitions of a single ore horizon by folding. He points out that the ore bodies all possess the same general structure, and states that the central portions of all the lenses carried the purest ore, while in their upper and lower edges the magnetite was largely replaced by hornblende, augite and biotite. The mines are considered as belonging to two groups, distinguished by differences in the dip and pitch of the ore bodies—the Blue mine group and the Peter mine group. In the latter group the dips of the ore bodies are between 60° and 80° and their pitch 35° northeast, except in the Hope mine, where the dip is 55° northeast. This difference is explained as due to a difference in "original deposition." In the mines of the Blue mine group the plane of the ore bodies is vertical and their pitch 60° northeast. Between these two groups lie the Bush mine (Fig. 30), with a dip of 70° southeast and a pitch of 45° northeast, the Miller, Keeler and St. George mines, with dips of 63° southeast and a pitch of 40° northeast, and the Cooper mine with a dip and pitch corresponding with these features of the Peter mine. In explanation of this method of distribution of the ore bodies, Nason's suggestion is that the Blue mine group is on the limbs and the apex of a syn-

cline, the Peter and Hope mines on the west limb of another syncline, with the Bush, Keeler and Cooper mines on the west side of the intervening anticline. He illustrates his contention with a

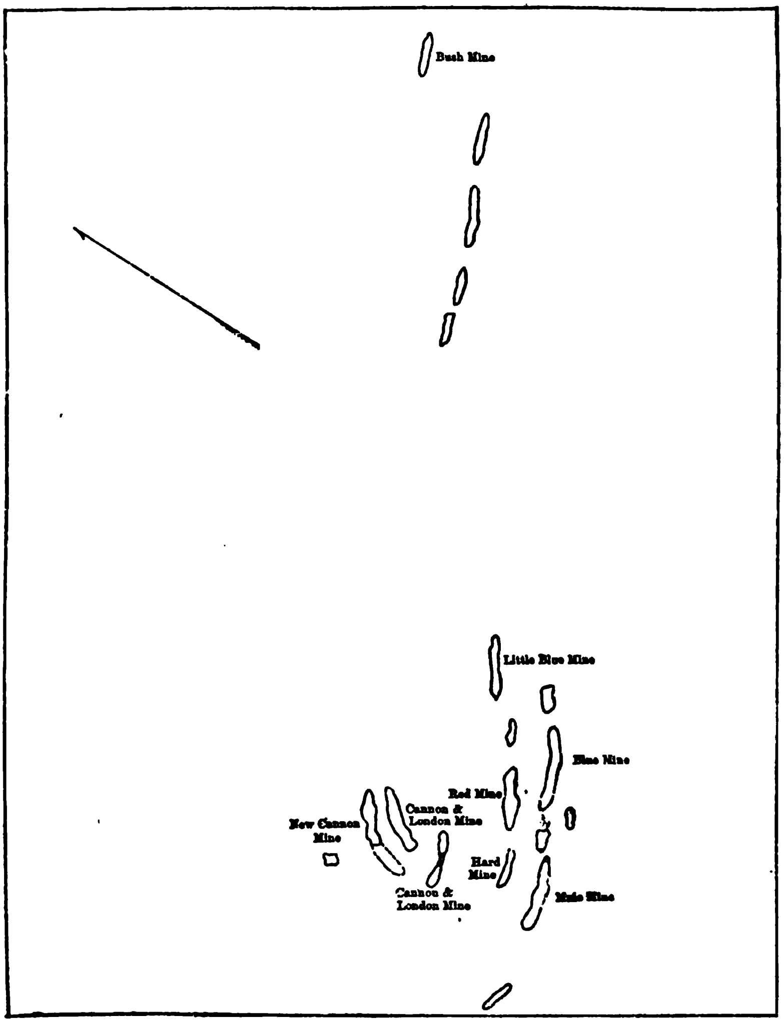


Fig. 30.

Sketch may, showing relative positions of the Blue Mine and Bush Mine groups at Ringwood. Scale, 1 inch. = 400 feet. (After F. L. Nason, Trans. Amer. Inst. Min. Eng. Vol. 24, p. 519.)

plan of the assumed folds, which is reproduced in Fig. 31. This theory is based on such a slight foundation that it can hardly be considered seriously. It is just as probable that the Bush and other mines in its vicinity are on the continuation of the Blue

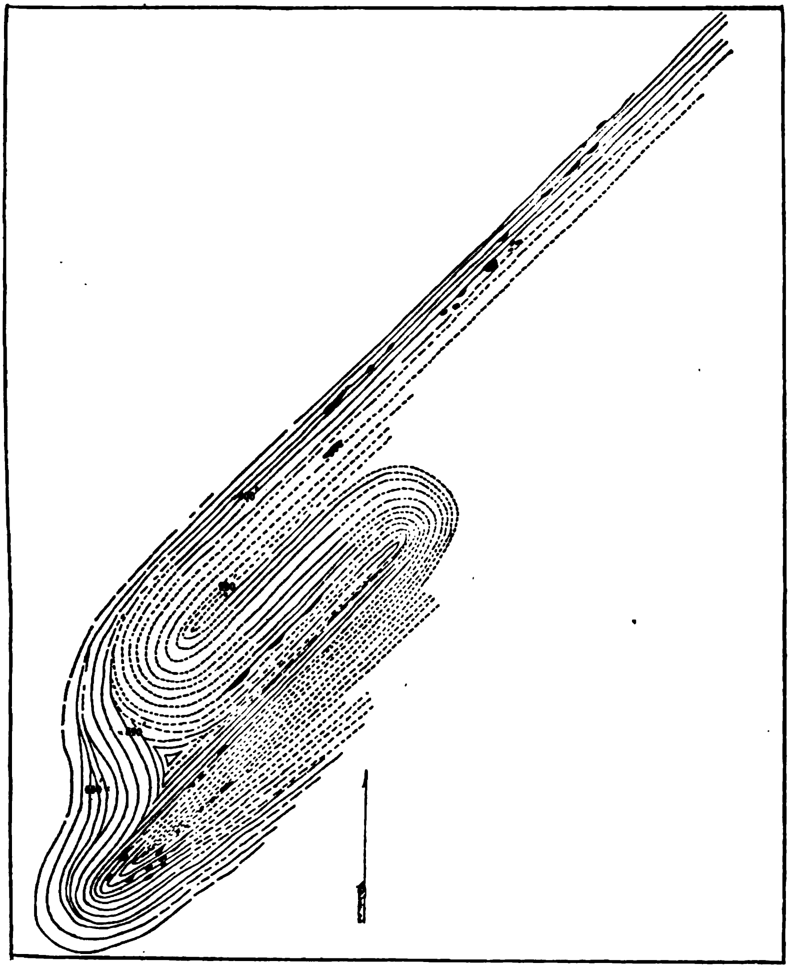


Fig. 31.

Sketch illutsrating supposed folding of rocks at Ringwood. Scale, 1 inch = 2,050 feet. (After F. L. Nason, Trans. Amer. Inst. Min. Eng. Vol. 24, p. 509.)

The heavy black spots represent mines actually worked. Fine lines represent actual rock outcrops where dip, strike and pitch were observed; dotted lines, conjectural strikes, etc.

mine vein, brought to the surface by a fault between the two. This view receives some support from the fact that in the vicinity of the Cannon mine there are numerous parallel ore shoots that are in a general line with the shoots of the Peter mine, but which at several places appear to have suffered a slight displacement to the left. The distribution of the mines might be explained on the supposition that the ore bodies lie in a single vein, or possibly two parallel veins, shifted to the left as they are traced northeast by a number of cross-faults. A third hypothesis considers the deposits as being on independent veins.

The total yield of the entire group of mines to June, 1880, is estimated in the Report of the 10th Census at 896,000 tons of ore. This was contributed mainly by the Cannon, Hurd, Keeler, Peter and Blue mines and the various openings on Hope Mountain. Before 1880 all these mines except the Cannon and a few small openings on Hope Mountain had been abandoned. and the Peter mine began to be again prominent as a producer. The New Miller was also worked a short time in the early 80's. Since 1886 all the ore has been obtained from the Peter mine except a comparatively small quantity that was taken from the Cannon mine. The total production of the group since 1880 has been about 325,000 tons, which, added to the 896,000 tons produced prior to this time, gives an aggregate of 1,221,000 tons as their total production to the close of 1907.

References: N. J. 1840, pp. 23–27; 1855, pp. 180–186; 1868, pp. 546–550; 1873, pp. 52–54; 1879, p. 61; 1880, p. 109; 10th Census, pp. 174–175; 1883, pp. 120–122; 1884, pp. 92–93; 1886, p. 150; 1890, pp. 67–68; 1891, p. 249; 1896, p. 333; 1899, p. 160; Trans. Amer. Inst. Min. Eng., Vol. 24, p. 505; 1900, p. 205; 1901, pp. 148–149; 1902, p. 122; 1903, pp. 106–107; 1904, pp. 300–301; 1905, p. 317; 1906, p. 175; 1907, p. 171.

(337) The Blue Mine was on the southeasternmost of the Ringwood ranges. It was first opened about 1835. By 1840 the ore had been removed from a pit which is described as being 100 feet long, 50 feet deep and from 6 to 15 feet wide. It was again opened in 1853 by a shaft that was sunk to a depth of 130 feet. A tunnel was also driven 175 feet from the southeast slope of the hill on which the mine was situated. This intercepted the ore body 30 feet below the surface. In the next two

years about 6,000 tons of ore were raised from an irregular deposit from 10 to 20 feet thick, and 100 feet long, measured horizontally. By 1868 this deposit had been worked through a distance of 300 feet on the pitch, which was 60° northeast. Its dip was nearly vertical and its width about 17 feet. The mine was idle in 1873.

The ore was massive and light blue in color. Its composition as given in 1868 showed a content of 68.1 per cent of iron. The following analysis was published in 1873:

Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	TiO_2	*Ins.*	*Total*	*Authority*
95.98	.66	...	.43	.06	1.95	4.10 =	103.18.	N. J. 1873, p. 54

Within an area of a few hundred square feet, in addition to the Blue mine there were three other considerable mines, namely, the Mule mine, which was southwest of the Blue mine; the Hard mine, which was west, and the Little Blue mine, which was north.

The ore body in the Mule mine was 60 feet long and 14 feet to 20 feet wide. It pitched 45° northeast. The mine was opened about 1835, and abandoned in 1840. The ore is reported to have been very fine.

The outcrop of (338) Hard mine was 150 feet long but very narrow. It was opened before the Revolution and had been worked down more than 175 feet before 1855, when it was abandoned. It was reopened again about 1870 and in 1873 had been mined to a depth of 400 feet. It was soon afterward abandoned permanently.

The Little Blue mine ore body had a length of 40 feet and a breadth of 8 feet. In 1868 the ore had been removed to a depth of over 100 feet.

The ore of the Hard mine analyzed:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	P_2O_5	S	TiO_2	*Ins.*	*Total*	*Authority*
90.14	0.30	1.00	2.13	0.94	1.86	0.01	0.40	5.60=	102.38.	N. J. 1873, p. 54

References: N. J. 1840, p. 24; 1855, pp. 182–183; 1868, p. 547; 1873, pp. 53–54.

The New or Wood mine was 400 yards northeast of the Blue mine. It was opened during the winter of 1854. The ore deposit was 12.5 feet thick, including 5 feet of rock. It dipped 88° southeast and pitched 30° northeast.

Reference: N. J. 1855, p. 182.

(339) The Bush mine was about one-fourth of a mile northeast of the Blue mine, and was for a long time considered as being on the same range as this mine. Nason, however, regarded its position on a line which lies between the Cannon and the Blue mines as explainable by folding.

The mine was probably opened about 1855. In 1868 ore had been removed from a pit 100 feet long and 70 feet wide. The ore body dipped nearly vertical and pitched 30° northeast.

The ore was compact, granular and black. It contained a little hornblende and a few veins of quartz.

Reference: N. J. 1868, pp. 547–548.

The Cook mine was near the Hard mine. It was opened about 1867 on a comparatively large ore body, but so far as known was never worked.

Reference: N. J. 1873, p. 52.

(340) The Cannon mine was formerly the most important of the mines in the Ringwood group. It was at the southwest end of a vein about 400 feet northwest of that on which the Blue mine was situated.

The mine is an old one, but just when it was opened is not known. In 1855, however, extensive pits had already been made and large quantities of ore had been removed from them. Within an area of 125 feet by 100 feet there were apparently four deposits of ore. The southwest one was 25 feet long and 10 feet wide. From this about 200 tons had been taken before 1855. Another was at the southeast end of the pit. This was 50 feet long and 34 feet wide. It was worked in the very early years. The other two were in the northwest portion of the pit. These were 60 feet by 13 feet and 50 feet by 20 feet. They were both worked to a depth of 25 feet to 30 feet by the London Company. The entire rock between the ore bodies was so thickly impregnated with magnetite that it was all mined together in later years so that it constituted a mass of ore about 125 feet by 100 feet in size. The whole body apparently pitched northeast beneath a "cap rock" at an angle of 45°. The wall rocks were

remarkable for being grooved with furrows sloping in the direction of the pitch of the rock. In the vicinity of the mine there is much pegmatite composed of a bright-red feldspar, quartz, and hornblende or pyroxene. This often encloses masses of ore. The quartz occasionally contains crystals of rutile. Zeolites and asbestus were also observed in cracks in the neighborhood of the ore bodies. The mine was worked almost continually between 1855 and 1879.

The ore varied in color and in coarseness of structure. When powdered some of it possessed a purple tinge and other parts a distinct red color. This was thought to indicate that hematite was intermingled with the magnetite, which, of course, constituted its principal portion.

A sample of ore taken from the cars in 1880 analyzed:

Fe=55.25; *P*=1.567. Authority: 10th Census, p. 175.

Samples analyzed in 1873 gave:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	*Insol.*	*Total*	*Authority*
1—65.95	0.0	5.09	6.83	0.07	0.0	5.56	0.80	18.10	=102.40	N. J. 1873, p. 53
2—76.08	0.0	1.94	7.77	0.14	0.0	6.59	0.70	7.00	=100.22	N. J. 1873, p. 53
3—96.16	0.0	1.74	0.0	0.22	0.0	tr	0.70	3.10	=101.92	N. J. 1873, p. 53
4—90.47	0.0	1.91	0.0	0.72	0.0	tr	2.72	5.80	=101.62	N. J. 1873, p. 53

The Saint George mine was in a small deposit on the trend of the Cannon vein and very close to this mine. It was worked before 1863 on an ore body that was reported to be 30 feet wide, and which was supposed to be connected with the Cannon mine shoots.

An analysis of the ore made in 1873 gave:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	*Insol.*	*Total*	*Authority*
94.66	0.20	0.39	2.58	0.21	0	2.50	0.65	2.00	=103.19	N. J. 1873, p. 53

References: N. J. 1868, p. 548; 1873, p. 53.

(341) The Miller mine was also on the trend of the Cannon vein. It was opened about 1867, revealing an ore body about 12 feet wide from which 1,000 tons of ore were taken during the first year. It was worked for several successive years, but was not in operation during 1873. In 1881 a new opening was made under the name of the New Miller mine, and was operated until 1884.

The shoot of the New Miller mine was large, having horizontal dimensions of 300 feet by 20 feet. At a depth of 150 feet a pinch was encountered in which the width of the ore was reduced to 5 feet. The dip of the deposit was about 60° southeast and its pitch was northeast.

A sample of the ore analyzed in 1873 gave:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	Insol.	Total	Authority
84.56	0.25	3.00	5.04	tr	0	4.74	0.50	4.60	=102.69	N. J. 1873, p. 53

References: N. J. 1868, p. 548; 1873, p. 53; 1880, p. 109; 1883, pp. 120–121; 1884, pp. 92–93.

(342) The Keeler mine was about one-half a mile northeast of the Cannon mine, on what is apparently a distinct vein a few hundred yards further west.

Like the other mines of the Ringwood group it was first worked by an open pit, which, in 1868, was 70 feet long, 20 feet wide and 15 feet deep. Magnetic attraction, however, indicates extensions at both ends of the developed portion of the mine. The dip of the ore body was 63° southeast and its pitch 40° northeast. If this mine is identical with the Caler mine of the early reports, it was opened by the London Company, and reopened again before 1855. About 5,000 tons of ore had been removed at that time. The mine was idle in 1873 and had been idle for some time previously, except during short periods when small quantities of ore were taken out for use in the forge at Bloomingdale.

An anlysis of the ore published in 1873 was as follows:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	Insol.	Total	Authority
78.3	0.25	1.17	4.03	tr	0.01	3.39	1.44	12.60	=101.19	N. J. 1873, p. 54

References: N. J. 1855, pp. 181–182; 1868, p. 548; 1873, p. 53.

The Cooper mine was situated on a vein between the Keeler and the Peter mines. The opening was about one-quarter of a mile south of the last-named mine.

It was opened a few years before 1868, and at this time had been worked for a length of 80 feet. The pit was 10 feet wide and in one place was 30 feet deep. The mine was operated between 1868 and 1873, but soon after the latter date was closed.

Ore analyzed in 1873 had the following composition:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	*Insol.*	*Total*	*Authority*
85.08	0.20	2.80	6.62	0.28	tr	5.12	tr	3.10	=103.20	N. J. 1873, p. 54

References: N. J. 1868; p. 548; 1873, p. 53.

(343) The Peter mine was situated about 1 mile northeast of the Blue mine at the southwest end of the northwestern range. It was opened before the Revolution and worked by the London Company through several shafts and an adit.

After producing about 50,000 tons of ore the mine was abandoned. It was reopened in 1837 and 1,000 tons were removed, when it was again closed before 1855. In the early years the mine was the main reliance of the two furnaces on the Ringwood property. In 1868 the pit from which the ore had been removed was described as being 150 feet long and 50 feet wide. The mine was idle in 1873. Ten years later, however, it was being operated in connection with a new opening which was known as the New Peter mine. The two mines were in parallel shoots which united a short distance beneath the surface. The northwest, or old Peter, shoot had a length of 60 feet and a height of 70 feet, with a breadth of 30 feet. It dipped 60°–75° southeast and pitched 40°–50° northeast. The southeast shoot was 20 feet high and had a breadth of 10 feet. Its dip was nearly vertical. In 1884 a new shoot was discovered northeast of the Old Peter shoot, but was not tested, as work was suspended at both mines during this year. By 1886 work had been resumed and a new shaft was sunk northeast of the old workings. In 1890 the ore came to an end suddenly in the bottom of the mine, possibly as the result of faulting, since there was no gradual thinning of the ore body, as would have been the case had it been pinched out. In the following year the pillars were removed and the walls were stripped, yielding a product of 20,000 tons.

The mine was reopened in 1899 and has been worked intermittently since this time. In 1905 a new slope was erected at the southwest end of the large open pit. This extends through the old pit for a distance of 440 feet at an angle of 40° and then drops vertically. Three new ore shoots were penetrated, two of which were each 16 feet high and 10 feet wide, and the third

40 feet high and 16 feet wide. The ore is rich, containing as it does 65 per cent. Fe. In the hanging wall of the bottom shoot a fourth shoot was later discovered, which was separated from the main shoot by 8 feet of a rock described as pegmatite. This new shoot is 8 feet thick, and consists of very rich ore. No mining was done in this year nor during the early part of 1904, but in the latter part of the year active operations were resumed and a small amount of ore was raised from a shaft northeast of the pit, which cut the two ore shoots known as Nos. 4 and 3, both of which were known from the open-cut work. The new shoot was 8 feet from the hanging wall at the bottom of the shaft. The mine has continued in operation to the present time.

An analysis of a sample of the ore, published in 1873, gave:

Fe_2O_3	MnO	Al_2O_3	CaO	MgO	S	P_2O_5	TiO_2	*Insol.*	*Total*	*Authority*
91.11	0.20	3.19	1.23	tr	0	0.90	0.30	5.40	=102.33	N. J. 1873, p. 54

Another sample obtained from the cars in 1880 gave:

Fe=55.56; *P*=1.556. Authority: 10th Census, p. 174.

References: N. J. 1840, pp. 25–26; 1855, p. 181; 1868, pp. 548 and 550; 1873, p. 53; 1880, p. 109; 10th Census, pp. 174–175; 1883, pp. 120–121; 1884, pp. 92–93; 1891, p. 249; 1903, pp. 106–107; 1904, pp. 300–301; 1905, p. 317.

(344) The Hope mines were northeast of the Peter mine, apparently on the same ore range. They were situated at the base of the southeast slope of Hope Mountain. In all, the group comprises nine or ten pits, extending through a distance of 1,200 feet. Before 1840 two of them had been worked sufficiently to warrant recognition as distinct mines under the names the Spanish Hope and the Good Hope, the latter of which was northwest of the former. These mines were opened by the London Company before the Revolution. They were reopend in 1820, but were again closed before 1840. The Oak mine referred to below was also one of this group.

All the mines on Hope Mountain were permanently abandoned before 1868, although in 1880 a little exploratory work was done on the slope of the hill west of the main pits. It is evident from the size of some of the openings that considerable ore had been raised from them. One of the larger pits, of which there are five or six, measures 100 feet in length and 30 feet in

width. The vein probably consisted of pinches and shoots with consequent great variation in the thickness of the ore body. The general dip of the vein was 85° southeast, and the pitch of the ore bodies about 55° northeast.

The ore from some of the openings is said to have been of superior quality. Two analyses published in 1868 indicate that it was very rich if the samples tested represent the ore as a whole.

These analyses are:

	Fe_3O_4	SiO_2 *and ins.*	*S*	P_2O_5	*Fe*	*Authority*
Old Hope, ...	95.7	3.1	0.0	0.3	69.3	N. J. 1868, p. 550
New Hope, ...	96.8	3.0	0.0	0.4	70.1	N. J. 1868, p. 550

Analyses published in 1873 (N. J. 1873, p. 54) are:

	Fe_3O_4	*MnO*	Al_2O_3	*CaO*	*MgO*	P_2O_5	*S*	TiO_2	*Insol.*	*Total*
Old Hope,.	94.06	0.25	2.59	1.57	0.22	0.45	....	0.30	3.00	=102.44
New Hope,	97.29	0.35	0.52	0.62	tr	0.47	tr	0.52	2.60	=102.37

In 1880 samples taken from (1) the opening on the slope of the hill that was worked at this time and (2) from the newer openings at the bottom of the hill gave:

(1) *Fe*=63.20; *P*=0.448. Authority: 10th Census, p. 175.
(2) *Fe*=62.66; *P*=0.458. Authority: 10th Census, p. 175.

References: N. J. 1840, p. 181; 1855, p. 26; 1868, p. 549; 1873, p. 54.

The Oak mine was an old opening on the southeast slope of Hope Mountain, about 1.5 miles northeast of the Hard and Blue mines. It was opened by the London Company in 1762 or 1763, and when abandoned was 30 feet deep. It was re-opened before 1853 and worked to a depth of 60 feet. The ore formed an irregular deposit, pitching 55° northeast. Several openings were made by the London Company to the southwest of the mine, but little ore was obtained from them.

Reference: N. J. 1855, p. 181.

Of the remaining three mines of the Ringwood group that are referred to by name in the literature, viz., the Ward, the Winslow and the Little Red mines, very little is known. They were probably all in the nature of exploratory pits. The Ward

mine was opened about 1874, but was not worked. The other two mines were probably opened about the same time.

Reference: N. J. 1874, p. 26.

THE POTTERSVILLE-HEWITT BELT.

The Pottersville-Hewitt belt of mines contains a few scattered openings from which ore has been taken. None of them have been important mines, nor has any physical connection between them been discovered. They appear to be on independent ore bodies.

The Pottersville Openings.

A number of openings in search of ore were made in the vicinity of Pottersville during 1871 and 1872, but only two ever produced ore in sufficient quantity to be shipped.

One of the most important of these was on the south side of the road between Pottersville and Fairmount, in Tewksbury Township, Hunterdon County. This was known later as the Pottersville mine (see below). Another was 1.5 miles northwest of the village on the Fox Hill road. This afterward became the Bartle mine (see p. 467). A third opening was one-half of a mile northeast of the village, near the Chester road. This disclosed a vein of good ore, but it was so small that the exploration was soon abandoned. About 2 miles west of Pottersville was a fourth opening, of which nothing is known. It may be that it was the Welch mine of later reports (see p. 460).

The Pottersville mine, or Updike Farm mine, was on the south side of the road to Fairmount, in Tewksbury Township, Hunterdon County.

It was opened in 1872 on a side hill 200 feet above a tributary of Black River. A vein of ore 5 feet wide was discovered with hard, firm walls running east-west. About 100 tons of ore were mined and then the place was abandoned.

References: N. J. 1873, p. 30; 1879, p. 46; 1883, p. 85.

(345) *The Wortman Mine.*

The Wortman mine was in Chester Township, Morris County, a short distance west of the road between Hacklebarney and Pottersville.

Two shafts were dug about 1873 to a depth of 35 feet. It is reported that the red ore at the surface was of good quality. Nothing more is known of the occurrence.

References: N. J. 1883, p. 85.

(346) *The Lewis Mine.*

The Lewis, or Herrick, mine was in Mendham Township, Morris county, about 2 miles southwest of Calais, and three-fourths of a mile south of the Combs mine.

There is no record as to the date at which this mine was opened. It was abandoned, however, in 1870, and remained closed until 1880, when a little work was done looking to its reopening. Three shafts had been sunk, one of which was reported to be 100 feet deep.

The ore was coarsely crystalline and mixed with a green mineral, which may have been chlorite. The vein was 4 to 6 feet wide.

References: N. J. 1873, p. 42; 1879, p. 50; 1880, p. 104.

(347) *The Hewitt Mine.*

The Hewitt mine was east of the range of Ringwood mines and further north, on a knoll about 1.5 miles northeast of Ringwood. In the descriptions of the New Jersey mines in the various reports of the Survey the mine is recorded as being situated in Pompton Township, Passaic County, but on the maps of the Survey it is located north of the State line, in New York.

The mine was worked before 1868 and again in 1880, but for how long a period in each case is not known. In 1880, however, the ore had been removed from an open cut to a depth of 25 feet with a breadth of 8 feet.

Analyses of the ore made at different times give widely varying results, as follows:

Fe	*S*	*P*	*SiO_2 and ins.*	*Authority*
45.4	2.3	tr	19.1	N. J. 1868, p. 550.
52.32	3.324	0.078	....	10th Census, p. 175

Fe_2O_3	*MnO*	*Al_2O_3*	*CaO*	*MgO*	*S*	*P_2O_5*	*Insol.*	*Total*	*Authority*
69.64	0.15	9.17	....	tr	4.54	0.19	17.30	= 100.99	N. J. 1873, p. 54

References: N. J. 1868, p. 549; 1873, p. 53; 10th Census, p. 175.

THE ROCKAWAY VALLEY BELT.

The Rockaway Valley belt of mines is poorly developed. Aside from the opening northeast of Pottersville and a few exploring pits north of Taylortown it has been worked only at the Rockaway Valley mines. As a matter of fact there is no distinct belt here, although the various openings are considered as constituting a belt as a matter of convenience. The Pottersville explorations have already been referred to (page 486).

(348) The Botts Farm Mine.

The Botts Farm mine was about 1.5 mile north and a little east of Powerville, on the south side of the road leading west from Taylortown, in Pequannock Township, Morris County. The mine opening is nearly in the line of strike of the ore lead passing through the Decker mine, which is about a mile further north, and therefore is a little east of that on which the Rockaway Valley mines are situated.

The mine was opened for exploration in the winter of 1872–3 by a shaft 23 feet deep, and about 70 tons of ore were raised. The ore body is between 3 and 4 feet wide and the ore is of about the same character as that of the Rockaway Valley mines.

References: N. J. 1873, p. 49; 1879, p. 60; 1880, p. 109; 1883, p. 119; 1884, p. 91; 1890, p. 105.

(349) The Rockaway Valley Mines.

The De Camp, or Rockaway Valley, mines comprised a number of pits and shafts situated on the west slope of Rock Pond Moun-

tain, 3 miles north of Powerville, in Pequannock Township, Morris County.

The ore body was first explored in about 1820, but was not further tested until 1870, when five openings were made which disclosed the ore in a lead of at least three-quarters of a mile in length. The mine was worked until the panic of 1873, when it was closed, to be reopened again in the fall of 1879 and worked for a short time, after which it was abandoned. In 1872 the yield was at the rate of about 450 tons per month. In 1879–1880 about 500 tons were raised.

The ore here occurs in a succession of shoots pitching about 45° northeast and dipping 60° southeast. The ore bodies were about 4 feet wide and 50 feet long in the outcrop. The ore was hard, close-grained and contained a little pyrite. Several small veins parallel to the larger one occur near the latter, but their small size, and the fact that their ore is sulphurous, prevented their being worked with the larger one.

Southwest of the openings above referred to, and in the same lead, two other shafts were sunk in 1872 and 500 tons of ore were removed. The ore body at this place was also in the form of a shoot descending steeply to the northeast. The ore, however, differed from that of the mines to the northeast in consisting of alternating laminæ of coarse and fine material. Still further southwest on the same line other openings were made, but the ore was found to be too lean to warrant working.

References: N. J. 1873, p. 50; 1879, p. 60; 1880, p. 109; 1883, p. 119; 1884, p. 91; 1890, p. 105; 10th Census Report, p. 174.

(350) The Decker Mine.

The Decker mine is on the same ridge as the Rockaway Valley mines, but on its east slope. A shallow trench and a few holes put down in 1872 uncovered an ore body 12 feet wide. The work was not followed up.

References: N. J. 1873, p. 51; 1879, p. 60; 1880, p. 100; 1883, p. 110; 1884, p. 91; 1890, p. 105.

(351) The Cole Farm Exploration.

The Cole Farm exploration was 3 miles north of Boonton, near the Butler-Boonton road. It is reported as being in Montville Township, Morris County, but if it is the place indicated on the topographic map as 1 mile northeast of the Decker mine, it is in Pequannock Township.

The work was done about 1874. A lean ore was found between walls dipping steep to the northwest. The magnetic attraction is reported to be strong and steady for a long distance. So far as known no further work has been done at the locality.

References: N. J. 1874, p. 21; 1879, p. 41; 1884, p. 73.

The Gould's Farm Mine.

The Gould's Farm mine is another exploration only. The opening was one-half mile southwest of Brook Valley, in Pequannock Township, Morris County, but its exact location is unknown. The farm of A. Gould is indicated in the county map of 1873 as being northwest of Brook Valley.

A strong magnetic line, which is said to extend for a distance of 1,500 feet, was explored by diamond drills about the year 1873, and a body of ore 5 feet wide was encountered which dips steep to the southeast. Nothing is now known of the character of the ore, as there is no record that the explorations were followed by active mining.

References: N. J. 1873, p. 51; 1879, p. 60; 1880, p. 109; 1883, p. 119; 1884, p. 92; 1890, p. 105.

THE KAHART MINE BELT.

The Kahart belt of mines, like the others of these eastern belts, is mainly one of exploration. It contains only two mines from which any ore has been shipped commercially. All the ore, so far as it has been developed, is lean and in narrow veins.

(352) The Auble Mine.

The Auble mine was 1.5 miles northeast of Gladstone, in Bedminster Township, Somerset County.

It was reopened in 1890 in an old prospect hole by a shaft 50 feet deep. The mine at the end of the year was 100 feet long. By the close of 1891 two shafts had been sunk, one 120 feet deep and the other 80 feet deep, and these had been connected by a drift 140 feet long. The vein was only 3 feet wide, but the ore was said to be of Bessemer quality. About 400 tons were raised. Work soon ceased and the mine was abandoned.

References: N. J. 1890, p. 67; 1891, p. 241.

(353) The Connet Mine.

The Connet, or Water Street, mine was on the south side of Whippany River, at Brookside, in Mendham Township, Morris County.

The first opening at this place was a tunnel driven from near the river southward into the vein for a distance of about 200 feet, presumably in search of copper ore. This tunnel was reopened in 1869 and followed into a vein of magnetic. This was then drifted into for a distance of 300 feet, where the ore body became too narrow to warrant further working. A second tunnel 500 feet long was driven along the vein beneath the first one.

Throughout its entire length the vein, which was between 4 and 7 feet wide, strikes southeast and dips southwest at 45°. The pitch of the ore shoots was southeast.

The ore was contaminated in places by hornblende and pyrite. It is not known how long the mine was worked, but it has produced nothing since about 1875. When actively operated its yield was 4,500 tons annually.

References: N. J. 1873, p. 25; 1879, p. 41.

(354) The Beers Exploration.

The Beers exploration was near Morris Plains, in Hanover Township, Morris County, but the exact location of the holes put down has not been ascertained. They were probably near the Asylum.

The first explorations were made in 1878, and these were followed in the succeeding year by others. One shaft 25 feet

deep was sunk, and from this about 30 tons of ore were raised and shipped. It is said that "no regular vein" was struck.

Specimens obtained from the first holes dug showed the presence of a large percentage of titanium, as the following analysis indicates:

Fe	*Mn*	*S*	*P*	*TiO_2*	*SiO_2 and insol.*	*Authority*
54.46	0	0.31	0.04	7.70	22.50	N. J. 1878, p. 00

References: N. J. 1878, p. 99; 1879, p. 41; 10th Census, p. 176.

(355) *The Taylor Mine.*

The Taylor mine is described as being east of Stony Brook Mountain, or Mine Ridge, near Taylortown, in Montville Township, Morris County. The mine hole is on the west side of the Boonton-Butler road, about one-fourth of a mile north of the road corners at Taylortown.

About 300 tons of ore were taken from the mine in 1858 or about that time. It was not worked again until 1873, when it was reopened for exploration. The ore was found to be rich and to be present in a body of from 2 to 3 feet wide, striking nearly east-west.

References: N. J. 1873, p. 25; 1879, p. 41; 1880, p. 101; 1883, p. 81; 1884, p. 73.

(356) *The Kahart Mine.*

The Kahart mine, situated about 3 miles south of Butler and about one-half mile east of the Boonton-Butler road, in Pequannock and Montville Townships, Morris County, was opened prior to 1868 and explored by diamond drill in 1872. The drilling revealed the presence of two ore bodies, one of which was 3 feet thick and the other from 3 feet to 6 feet thick. After the presence of these was discovered a shaft was sunk 20 feet, and then work was stopped. The mine remained closed until 1880, when it was reopened and worked for a few weeks, during which time about 50 tons of ore were raised. The rocks in the neighborhood of the ore body are reported to dip northwest.

The composition of the ore obtained from the shaft in 1872 was as follows:

Fe=52.34; P=0.17; S=1.23; TiO_2=1.40. Authority: N. J. 1873, p. 26.

References: N. J. 1868, p. 544; 1873, pp. 25–26; 1879, p. 41; 1880, p. 101; 1884, p. 73; 1890, p. 88; 10th Census, p. 176.

(357) The Beam Mine.

The Beam lot explorations were 2 miles north-northeast of Bloomingdale, in Pompton Township, Passaic County, in a valley between two knolls, about three-fourths of a mile southwest of Haskell.

The locality is an old one which had been explored and apparently abandoned until reopened in 1875 by a shaft 20 feet deep in a vein 4 or 5 feet wide. A little rich ore was raised, but the place was soon abandoned a second time only a few weeks after its reopening. At present two shafts can be seen and several large dumps.

Reference: N. J. 1879, p. 42.

(358) The Sloat Farm Mine.

The Sloat Farm openings are about 3.5 miles northeast of Midvale and three-fourths of a mile southwest of Conklintown, in Pompton Township, Passaic County.

The place was explored some time before 1882, but the first account of it appears in 1883. Four pits were made on the south and east slopes of a steep, wooded ridge, disclosing lean ore and a thin bed of good ore. The southernmost pit was 20 feet deep. The northernmost one was the more important. It is not known how deep it was, but its dump contains quite a large quantity of lean ore. A third hole was 250 yards northwest of the last mentioned.

A visit to the locality in 1907 showed the presence of two openings with large, fresh dumps that indicated very recent working. It is probable that no considerable quantity of ore was found. The country rock at the slope is a hornblendic gneiss, and this apparently passes gradually into ore.

Reference: N. J. 1883, p. 83.

THE KANOUSE MINE BELT.

The developed portion of the Kanouse mine belt is very short. It practically extends only 3 or 4 miles, crossing the Wanaque River at Pompton Junction. It has been explored at several points, at which only lean ore was obtained. Since, however, the phosphorus content of most of the ore found was low, there have been repeated attempts to discover a paying deposit upon it. The belt has never produced in commercial quantity, except at the Kanouse mine, and even here the prospects were not bright enough to warrant mining on a large scale.

The Bernardsville Mines.

This name is given to a number of openings made in 1870–71 on farms west of Bernardsville, in Bernardsville Township, Somerset County. Little ore was obtained, and the holes were abandoned after a short period of exploration.

References: N. J. 1871, p. 31; 1873, p. 24; 1879, p. 41.

(359) The Janes Mine.

The Janes mine, in Bernardsville Township, Somerset County, is described as an old mine situated on Mine Mountain, near the contact of the Highlands gneiss with the Kittatinny limestone. It was opened some time prior to 1865, but was never worked to any considerable extent.

References: N. J. 1868, p. 544; 1873, p. 24.

(360) The Lanagan Mine.

The Lanagan mine is reported to have been 2 miles northwest of Pompton Plains, near the border of the gneiss area in Pequannock Township, Morris County. Old residents in the vicinity declare that the mine was about one-fourth of a mile southeast of the De Bow shaft, and that the location of the mine 1.5 miles farther southwest, as shown on the topographic map, is an error.

At the point one-fourth of a mile southeast of the De Bow shaft is a deep hole at the base of a ledge of rock cut by a great quantity of pegmatite. A large dump surrounds the hole, but the rock in it is so weathered that little can be determined as to its nature. The few pieces of magnetite discovered in the pile were in a coarse pegmatite.

The mine is reported to have been opened between 1868 and 1873 by several shafts which disclosed the presence of some lean ore. The size of the deposit is unknown. The mine has not been worked since 1874.

At the point indicated on the map as the site of the Lanagan mine is a small hole from which some very lean material was taken. The quantity is so small, however, that it is certain that the place was never regarded as promising.

References: N. J. 1873, p. 26; 1839, p. 42; 1884, p. 73; 1890, p. 88.

(361) *The De Bow Mine.*

The De Bow, or De Bow Place, mine is described in the State Reports as being situated south of the Lanagan mine, but on the topographic map it is located northeast of a shaft which is indicated as being the Lanagan. This location is said to be the correct one by old residents in the vicinity, but that of the Lanagan mine is said to be an error (see p. 494).

The De Bow mine, known also as the Miller mine, was opened in 1872 on a long line of attraction. It was worked until 1874, and then closed after a great deal of work had been done. It is possible that it was opened again by a new shaft in 1880, and about 200 tons of lean ore were taken from it at this time. In any event, the mine has not been worked for many years.

In 1906 a shaft was sunk in rock a few yards northwest of the principal shaft of the De Bow mine, but no ore was found.

References: N. J. 1873, p. 26; 1879, p. 42; 1880, p. 101; 1884, p. 73; 1890, p. 88; 10th Census, p. 176.

(362) *The Jackson Mine.*

The Jackson, or Axtell, mine (called Pompton mine in the Report for 1868) was situated about a mile southwest of Pomp-

ton Church, and less than a quarter of a mile south of the Pequannock River.

It was opened about 1862 and operated for two years. In 1873 it was reopened and worked during a portion of the year, yielding about 500 tons of sorted ore. The vein is reported to be small and to be cut by a coarse granite, or pegmatite, which contains magnetite as one of its components.

The composition of the ore was:

SiO_2	Fe_3O_4	Al_2O_3	CaO	MgO	P_2O_5	TiO_2	S	*Total*	Fe	P
9.80	73.15	9.48	1.46	0.72	0.54	4.40	0.06	= 99.62	52.96	0.23

References: N. J. 1868, p. 544; 1873, p. 26; 1879, p. 42; 1884, p. 73; 1890, p. 88.

(363) The Ryerson De Bow Mine.

The Ryerson De Bow mine was at the foot of the gneiss hills west of Pompton station, about 150 yards south of the Pequannock River, and a quarter of a mile north of the Jackson mine, in Pequannock Township, Morris County.

The locality was explored in 1872 by a shaft, which discovered a lead 9 feet wide, dipping southeast, on a line of magnetic attraction that is strong for a distance of 100 feet. The ore contained some pyrite and hornblende. Two trial pits southwest of the shaft discovered lean ore. In 1874 operations ceased, and the mine was soon afterward abandoned.

It was again explored in 1880, and 112 tons of ore were raised, but soon thereafter the place was again abandoned. Again in the fall of 1906 it was tested by two shafts 1,000 feet apart, the northern one of which, 100 feet deep, was near the old opening. The southern one is supposed to be on a vein further east. Both veins are said to have been traced by compass readings a long distance, passing through the De Bow mine. Under its new management the mine was known as the Bishop and Search mine.

An analysis of a sample of 2 carloads shipped to Secaucus in 1907 yielded:

Fe	Mn	Al_2O_3	MgO	CaO	P	S	SiO_2
65.87	0	1.13	.46	.89	.092	.391	2.11

References: N. J. 1873, p. 27; 1879, p. 42; 1880, p. 101; 1883, p. 88; 1884, p. 73; 1890, p. 28; 10th Census, p. 176.

(364) The Brown Mine.

The Brown mine was 250 yards southwest of the Kanouse mine in Pompton Township, Passaic County.

A shaft of 26 feet in depth penetrated an ore vein more than 12 feet wide on a strong line of attraction. The ore was struck in 1874, and about 100 tons were removed in the first 4 months of operation. The mine was abandoned during the winter of 1874–1875, but was reopened in 1880 and worked a short time, yielding 250 tons per month.

The ore was moderately rich but it contained considerable sulphur. An analysis of the material from near the surface gave:

Fe=46.9; S=2.08; P=0.03. Authority: N. J. 1874, p. 22.

References: N. J. 1874, pp. 21–22; 1879, p. 42; 1880, pp. 101–102; 10th Census, p. 175.

(365) The Kanouse Mine.

The Kanouse, or Brown, mine is in Pompton Township, Passaic County, about 1 mile east of Wanaque, at the foot of Ramapo Mountain.

Before 1868 the mine had been opened at several points revealing a streak of ore at least 7 feet wide. At this time it had been worked by open pits, one of which was 30 feet deep. It was reopened again in 1873 and 1874, and four shafts were put down from which 2,000 tons of ore were raised. The mine was again closed in 1875.

In 1882 explorations were resumed and a large sum was spent in preparing this mine together with adjacent Brown mine (see above) for operating. At this time there were two main shafts 1,500 feet apart and 100 feet deep, and drifts with an aggregate length of 600 feet. Several thousand tons of ore were raised. In 1890 the mine was again unwatered and explored, but the prospects did not seem sufficiently favorable to warrant working, although a great quantity of rock had been removed from the various openings.

The ore body dips southeast. The ore was very hard and compact and was intermingled with some marcasite or pyrite,

but it was low in phosphorus. Near the vein is an exposure of white limestone that has been serpentinized in part, but whether the ore is in this rock or not is not known. The line of attraction passing through the mine is strong for a distance of 600 feet in a northeast direction.

References: N. J. 1868, p. 545; 1873, p. 28; 1874, p. 22; 1879, p. 42; 1882, p. 71; 1883, p. 82; 1890, p. 89.

THE BUTLER MINE BELT.

The Butler mine appears to be on an isolated deposit, which is not on any distinct belt of deposits such as has been assumed to exist in connection with the other mines. At any rate no such belt has been developed in New Jersey. In New York there is an exploration pit, east of Tuxedo Park, and another east of Southfield, that are approximately in the strike of the Butler vein, and these three, with possibly some others farther to the northeast, may constitute a definite belt. In any event there are no openings on the New Jersey portion of the line except those of the Butler mine.

(366) The Butler Mine.

The Butler mine, in Hohokus Township, Bergen County, was on the Ramapo Mountains, about 3 miles west of Suffern.

Quite a little exploration had been undertaken before 1868. Pits and trenches uncovered a vein of good ore free from sulphur, 120 feet long, and varying from 5 to 11 feet in width, and with an additional 4 or 5 feet of ore and rock. Strong magnetic attractions were observed for a distance of 200 feet southwest of the openings. In 1873 and 1874 a little additional exploration was undertaken, and during the summer of 1879 some surface work was done. Three veins were uncovered, varying in width from 3 to 10 feet, and about 50 tons of ore were removed.

The mine was worked one month in 1880 and produced 280 tons of ore. It was then abandoned.

On the strike of the Butler vein, and about one-half mile to the

northeast, is the Pierson exploration, which uncovered the same lean ore as at the Butler mine. No ore was mined.

References: N. J. 1868, p. 544; 1873, p. 28; 1879, p. 42; 10th Census, p. 175.

MISCELLANEOUS NOTES.

The following analyses of magnetite ores have been published but without sufficient data to enable their locations to be identified:

Johnson Farm, near Glen Gardner. Surface ore contains 8.97% TiO_2. (Trans. Amer. Inst. Min. Engin., Vol. 21, 1892, p. 279.)

Property of Marcus Sayre, near Edison (?):

$Fe = 40.58$; $SiO_2 = 35.34$; $Ca = 0.08$; $P = 0.326$; $S = 0.106$; $TiO_2 = 2.27$ (N. J. 1899, p. 170).

A sample of ore obtained from the Bayard farm, near Allamuchy, on analysis by the chemists of the State Survey, gave:

$Fe = 49.5$; $TiO_2 = 5.9$; $P = $ tr; *Insol.* $= 26.6$. (N. J. 1875, p. 35.)

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GEOLOGICAL SURVEY OF NEW JERSEY

Maps Accompanying Report on IRON MINES AND MINING IN NEW JERSEY

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